BJC/OR-1410/R1

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Risk Screen to Support the Title Transfer of the K-1225 Building at the East Tennessee Technology Park, Oak Ridge, Tennessee

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Risk Screen to Support the Title Transfer of the K-1225 Building at the East Tennessee Technology Park, Oak Ridge, Tennessee

Date Issued—January 2004

Prepared by
Science Applications International Corporation
Oak Ridge, Tennessee
under subcontract 23900-BA-PR007U
under work release 000300

Prepared for the
U. S. Department of Energy
Assets Utilization

BECHTEL JACOBS COMPANY LLC
managing the
Environmental Management Activities at the
East Tennessee Technology Park
Y-12 National Security Complex Oak Ridge National Laboratory
Paducah Gaseous Diffusion Plant Portsmouth Gaseous Diffusion Plant
under contract DE-AC05-98OR22700
for the
U. S. DEPARTMENT OF ENERGY

03-110(doc)/010904

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ACRONYMS

BJC	Bechtel Jacobs Company LLC
COPC	contaminant of potential concern
cpm	counts per minute
CROET	Community Reuse Organization of East Tennessee
DOE	U. S. Department of Energy
dpm/100cm^2	disintegrations per minute per 100 square centimeters
EBS	Environmental Baseline Survey
EPA	U. S. Environmental Protection Agency
ESU	exterior survey unit
ETTP	East Tennessee Technology Park
EU	exposure unit
FSU	furnishings survey unit
ISU	interior survey unit
mrem/h	millirem per hour
NORM	naturally occurring radioactive materials
ORGDP	Oak Ridge Gaseous Diffusion Plant
pCi/g	picocuries per gram
QA/QC	quality assurance/quality control
RAGS	*Risk Assessment Guidance for Superfund*
RI	remedial investigation
ROD	Record of Decision
SAIC	Science Applications International Corporation
SVOC	semivolatile organic compound
UCL95	95% upper confidence limit
µrem/h	microrem per hour
VOC	volatile organic compound

EXECUTIVE SUMMARY

The goal of this risk evaluation is to determine the potential for adverse health effects associated with Bldg. K-1225 and determine if conditions preclude the use of the facility for its intended purpose, i.e., as an office building for the private sector. The U. S. Department of Energy is proposing to transfer title of this building to the Community Reuse Organization of East Tennessee.

K-1225 was built in 1980 as the office building for gas centrifuge personnel. It is a two-story structure constructed primarily of reinforced pre-cast concrete on a concrete slab. The total floor area is 23,500 ft^2. Since the shutdown of the gas centrifuge project in the late 1980s, other organizations have used the building for offices.

The Bldg. K-1225 area was farmland prior to the construction of the Oak Ridge Gaseous Diffusion Plant, later known as the K-25 Site and now known as the East Tennessee Technology Park (ETTP). During the construction of the process buildings in the 1940s and 1950s, there were hundreds of temporary buildings that provided support operations for the construction. These included warehouses, fabrication and maintenance facilities, cafeterias, housing, and offices.

One of the areas where there was a concentration of maintenance facilities was in the vicinity of the K-1225 building. From the 1940s through the late 1950s, this area was occupied by numerous support buildings. Of particular note is the former K-1044 building, a heavy equipment repair shop, that was located within the footprint of the K-1225 building. Building K-1044 included grease racks, a paint shop, and a heavy equipment store and later was a spare parts warehouse. During the sitewide remedial investigation, soil borings were made within the K-1044 area. Samples were collected from the borings from depths of 2 to 4 ft. These samples were analyzed for inorganic elements and semivolatile organic compounds (SVOCs). SVOCs were detected in a sample from only one of the borings, and all data were qualified as estimated. From this it was concluded that there was no subsurface contamination as a result of operations in the former K-1044 facility.

For Bldg. K-1225, the representative exposure scenarios considered for the risk evaluation were for the industrial worker and the roving worker. The industrial worker scenario, defined by an individual who spends time doing light industrial activities or office work within the building, is intended to represent exposure to contaminants on interior building surfaces. The roving worker spends break times during the workday outside the building roaming accessible areas of the industrial park. The exposure scenario for this worker is intended to represent exposure to contaminants in soils in the area surrounding the building.

The risk estimate is a value that represents the excess cancer incidence that might be expected due to the exposure scenario evaluated. The U. S. Environmental Protection Agency (EPA) has established a target risk range of 10^{-4} to 10^{-6}. The estimated average risk of 4×10^{-8} for Bldg. K-1225 is two orders of magnitude below the EPA target range, indicating a low likelihood of adverse health effects due to the exposure scenarios considered.

The risk calculations for Bldg. K-1225 were based on the most recent radiological survey data. For the surveys, the study area was divided into interior survey units (ISUs), furnishings surveys units, and exterior survey units (ESUs). For the risk assessment, it was assumed that furnishing remain in place and, thus, each ISU was assumed to include any furnishings. Because it was assumed that the worker would not engage in significant renovation of the building or spend significant amounts of time outdoors around the exterior of the building, exposures due to ESUs were not quantitatively evaluated.

The risks associated with an industrial worker at Bldg. K-1225 can be summarized as follows:

- the maximum risk associated with an individual survey unit was 6×10^{-8} for ISU 9, located in the northwest corner of the first floor;
- the maximum calculated dose was ~ 0.004 mrem/year for ISU 9, located in the northwest corner of the first floor;
- the upper confidence limit of 95% of the mean of the dose rate data was calculated to be ~0.005 mrem/h, which is below the site background level of 0.007 mrem/h;
- the average risk associated with the interior of Bldg. K-1225 was 4×10^{-8}, assuming a receptor is equally exposed to all interior survey areas; and
- the average calculated dose associated with the interior of Bldg. K-1225 was ~ 0.003 mrem/year for the interior of the building as a whole.

An additional scenario, the "rover" scenario, was evaluated. It assumes that the industrial worker spends 2 h per day moving around accessible areas of ETTP, both inside and outside of the fence, before the site has been fully remediated. The roving worker risk estimate quantitatively considered 45 surface soil contaminants of potential concern (14 metals, 16 organics, and 15 radionuclides) for the accessible areas of ETTP. The risk to the roving worker was 2×10^{-5}, which is within the EPA acceptable range of 10^{-4} to 10^{-6}. The risk was mainly due to external exposure to ionizing radiation, as well as both ingestion and dermal contact with polycyclic aromatic hydrocarbons. The calculated hazard for the roving worker was 0.3, which is below the EPA acceptable level of 1.0. For additional information, see Appendix A.

The risk evaluation for Bldg. K-1225 indicates that all risks, doses, and hazards are considered within acceptable levels of EPA's target risk range, which correlates with a low likelihood of adverse health effects to an industrial worker. Therefore, the facility is considered acceptable for transfer for its intended use as an office building by the private sector.

1. INTRODUCTION

The goal of this risk screen is to determine the potential for adverse health effects associated with Bldg. K-1225, located in the southeastern portion of the East Tennessee Technology Park (ETTP). The U. S. Department of Energy (DOE) is proposing to transfer title of this area to the Community Reuse Organization of East Tennessee (CROET) for its intended use by the private sector (e.g., use as an office building).

Specifically, the objectives of this evaluation are (1) to determine exposure to radiological constituents based on available data, and (2) to use these data to provide a screening-level estimate of the potential for adverse effects to human health. The risk screen approach used in this evaluation is based on the document entitled *Risk Assessment Guidance for Superfund* (RAGS) [U. S. Environmental Protection Agency (EPA) 1989]. The following sections describe the process used to provide a quantitative analysis of the risks to human health from working in the facility. The risk screen developed for Bldg K-1225 also includes a "rover" scenario to address an occupant who might potentially be exposed to contaminated soils as he or she moves around the accessible areas of ETTP prior to completion of site cleanup.

2. DESCRIPTION AND HISTORY

The K-1225 area was farmland prior to the construction of the Oak Ridge Gaseous Diffusion Plant (ORGDP), later known as the K-25 Site and now designated as ETTP, in the early 1940s. During the construction of the process buildings in the 1940s and 1950s, there were hundreds of temporary buildings that provided support operations for the construction. These included warehouses, fabrication and maintenance facilities, cafeterias, housing, and offices.

Building K-1225 is located in the southeastern portion of ETTP, inside the Radiologically Controlled Area fence (see Fig. 2.1). The building is a rectangular-shaped, two-story structure with about 11,750 ft^2 of floor space on each level for a total of 23,500 ft^2. It was built in 1980 to provide office space for gas centrifuge project personnel. The project was shut down in 1985, and since that time the building has been used by several organizations for offices. It is now an office facility for DOE's prime contractor at ETTP. Also included in the proposed title transfer is a 13.8-kV, dry-type electrical transformer that is located on the north side of the building. The transformer does not contain oil.

One of the areas where there was a concentration of maintenance facilities was in the vicinity of Bldg. K-1225. From the 1940s through the late 1950s, numerous support buildings occupied this area. Most of these facilities were demolished by the late 1950s, and their concrete slab foundations remained until the 1970s when the gas centrifuge program began a major expansion and construction project in the area. A portion of Bldg. K-1044 (a heavy equipment repair shop) was located within the K-1225 footprint. The heavy equipment repair shop was used to support the gas centrifuge program and included grease racks, a paint shop, and a heavy equipment store and later was a spare parts warehouse. In 1953 the building was sold and dismantled, leaving the concrete foundation. The foundation remained in place until the construction of K-1225 in 1980, when it was removed. Another building, Bldg. K-1045, served as a construction support building until 1947 when it was converted to an incinerator; it was used as an incinerator until 1953. Subsequently, the K-1045 building has been used for storage, a valve certification laboratory associated with the centrifuge project, and an office and break area. The building is currently used for storage of janitorial equipment. It is listed in Appendix C of the Federal Facility Agreement.[1]

[1]DOE, EPA, and TDEC 1994. *Federal Facility Agreement for the Oak Ridge Reservation*, Appendix C, "Oak Ridge Remediation Sites," FFA-PM/94-009, May 19, 1994 (modified on 2/13/02 per FFA-PM/02-022).

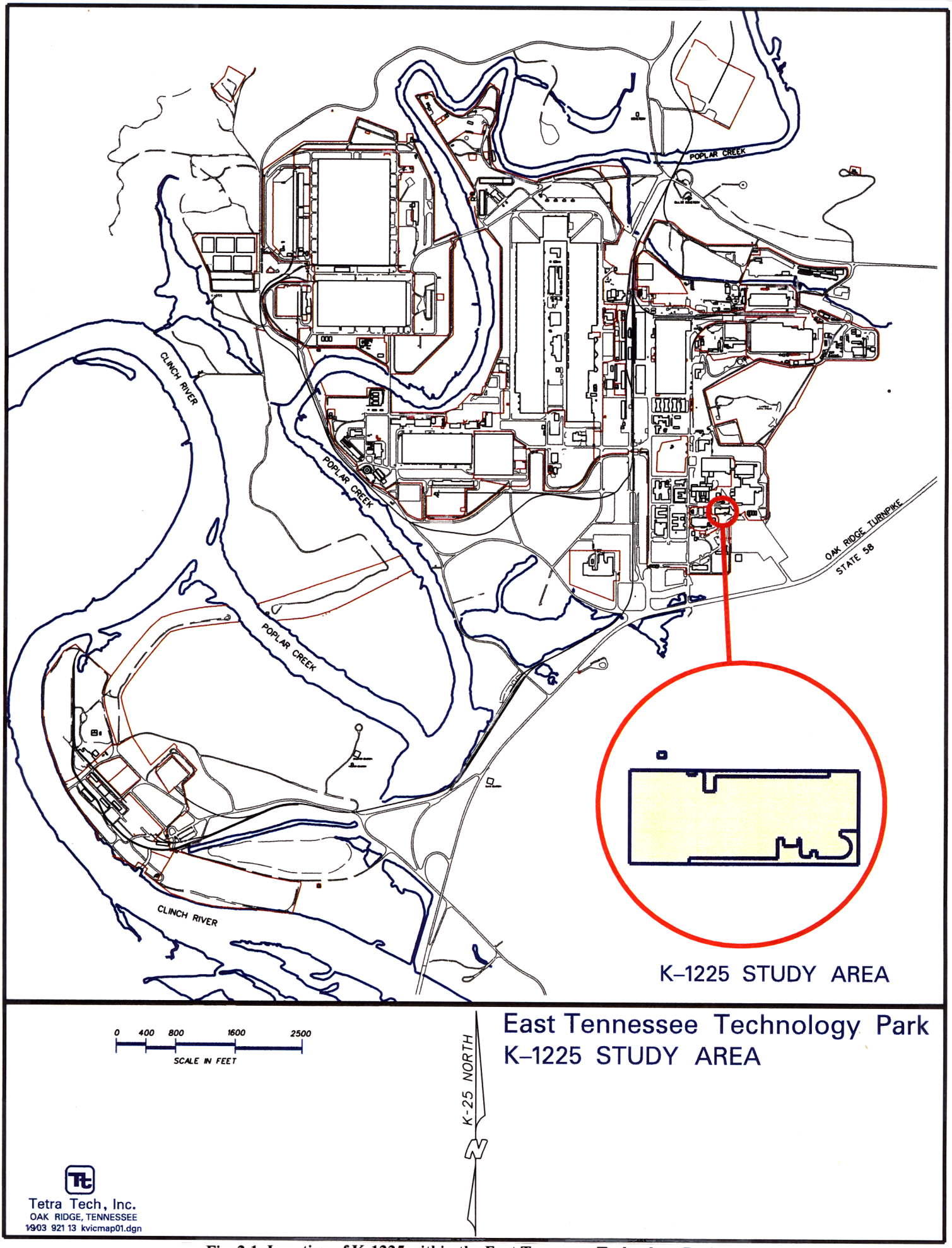

Fig. 2.1. Location of K-1225 within the East Tennessee Technology Park.

3. RADIOLOGICAL SURVEYS AND OTHER DATA

Since 1996, forty-three radiological surveys have been performed inside K-1225. Survey readings for all but one survey were below background levels. One survey had elevated beta-gamma readings; however, the elevated readings were taken in the restroom on ceramic floor tiles, which have naturally occurring radioactive materials (NORM) in their matrices. Sixteen surveys of office equipment, computers, and other miscellaneous materials were conducted in the building; no elevated activity above background levels was detected, except for computer monitors which have NORM in the phosphorus contained in the monitor screen.

In 2002, forty-eight radiological surveys [including all associated quality assurance/quality control (QA/QC) surveys] were conducted in the footprint in support of the proposed transfer. In addition, a supplemental survey of the transformer located on the exterior of Bldg. K-1225 was performed. Results of the surveys performed in the study area and the statistical test performed on the data gathered in each survey unit indicate that the interior, exterior, and present furnishings are below the DOE surface contamination limits and within the acceptable dose-equivalent range for building interiors. As the null hypothesis was rejected for each survey unit, based upon the non-parametrical statistical Sign test, then the alternative hypothesis is accepted, which states that the residual radioactivity in each survey unit does not exceed the derived concentration guideline limit and, therefore, the building can be released without radiological restrictions. There have been no chemical sampling events in the interior of the building to evaluate potential chemical contamination inside the building. Given the use of the facility as an office building since its construction, no sampling was deemed necessary.

The *Environmental Baseline Survey for the Title Transfer of the K-1225 Building at the East Tennessee Technology Park, Oak Ridge, Tennessee* (EBS) [BJC 2004] concluded that, due to the 1980 date of construction of the building, it is not suspected that the fluorescent light fixtures contain polychlorinated biphenyls in the ballasts. All insulation in the building is man-made mineral fiber. A 1995 asbestos survey of the K-1225 building reported that there are 318 ft^2 of assumed asbestos-containing material in the mastic for the stair treads, and asbestos was found in the black tar joint compound in 257 heating, ventilating, and air-conditioning duct joints throughout the building. These stair treads and duct joints, the assumed asbestos containing items, have not been replaced and are in good condition. The EBS concluded that due to the fact that the building was built in 1980, it is improbable that lead-based paint exists in the building. (The paint in the building is in good condition.) As long as the asbestos-containing material is maintained in good condition, exposure will not be a concern. Likewise, attention to the possibility of lead-based paint must continue.

Based on discussions with EPA, it has been agreed that the need to collect soil samples to support title transfer activities will be determined on a case-by-case basis. Factors, such as a facility's past operational history and geographic location, are considered. In addition, the history and knowledge of activities at adjacent properties are evaluated. As discussed in Sect. 6.2 of the EBS, historic and more recent document reviews of the K-1225 property and adjacent areas indicate that heavy equipment support activities took place from 1944 and 1953 within the present footprint and in the vicinity of K-1225.

Document reviews of the K-1225 property and adjacent areas indicate that there are locations of potential concern related to operations that took place in the area from 1944 through the 1980s. Information was gathered on these facilities from previously published reports. These include site historical investigations, the K-25 Site Access and K-25 Site Decontamination and Decommissioning Facility databases, and the *Site Descriptions of Environmental Restoration Units at the Oak Ridge K-25 Site* (Energy Systems 1995), which is discussed in Sect. 4.2 of the EBS (BJC 2004). Former facilities that have been demolished include the K-1236 Paint Shop, the T-27/T-5 Pipe Welding Shop, the T-17 Light Equipment Garage, the K-1045-A Waste Oil Burning Pit, the K-1044 Heavy Equipment Repair Shop, and the T-21 Oil/Grease Station. Facilities that are still present are the K-1045 Valve Shop, the K-1004-J Vaults, the K-1004-J Underground Tank, and the K-1004-L Pilot Plant.

One former facility, the K-1044 Heavy Equipment Repair Shop, was located within the K-1225 footprint. This facility is listed in *Site Descriptions of Environmental Restoration Units at the Oak Ridge K-25 Site* (Energy Systems 1995) as an environmental restoration unit in the Environmental Restoration Program. It is also included in Appendix C of the FFA. During the construction of K-1225, the removal of the foundation and site preparation redistributed the soils that would be associated with the former activities of K-1044.

During the sitewide remedial investigation (RI), soil borings were made within the K-1044 area. Samples were collected from the borings from depths of 2 to 4 ft. These samples were analyzed for inorganic elements and semivolatile organic compounds (SVOCs). SVOCs were detected in only one sample from the borings. From this, it was concluded that there was no subsurface contamination as a result of the former K-1044 facility.[2] There is an identified volatile organic compound (VOC) groundwater plume in the K-1200 area, but it does not extend under the former K-1044 site or K-1225.

Information on the hydrogeologic environment (including contaminant plume information) was provided in Sect. 4.3 of the EBS to present the potential for vapor intrusion in this area. Subslab soil vapor sampling will be conducted within K-1225 to determine if vapor intrusion is a complete pathway. The results of this sampling will be evaluated and will be made available to the public by posting them on a website, and an announcement will be made regarding their availability. Therefore, the exposure pathway for inhalation of VOCs via groundwater/soil vapor has not been evaluated in this risk assessment.

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[2]DOE 1999. *Remedial Investigation Report for the East Tennessee Technology Park, Oak Ridge, Tennessee*, DOE/OR/01-1778/V1&D1, U. S. Department of Energy, Oak Ridge, TN, October.

4. DATA DISCUSSION

The risk calculations for Bldg. K-1225 were based on the most recent radiological survey data as presented in the *Environmental Baseline Survey for the Title Transfer of the K-1225 Building at the East Tennessee Technology Park, Oak Ridge, Tennessee* (BJC 2004). The facility was divided into interior survey units (ISUs), furnishings survey units (FSUs), and exterior survey units (ESUs). For the risk assessment, it was assumed that the furniture would remain in place. Therefore, each ISU was assumed to include any current furnishings. Note that only ISUs and the FSUs are considered in the risk assessment. See Sect. 5.1.1 for information on how ESU data were evaluated.

Within each survey unit, radiological samples were taken to identify both removable contamination (smear activity data) and fixed contamination (total activity data). The risk assessment was based on data that were aggregated by sampling method (smear or total) and by survey unit. Table 4.1 provides a description of each of the 18 ISUs, and Fig. 4.1 shows the ISUs on a building map.[3]

Table 4.1. Interior survey unit descriptions

ISU Number	Description	ISU Number	Description
ISU1	1st floor, northeast corner	ISU10	2nd floor, northeast corner
ISU2	1st floor, southeast corner	ISU11	2nd floor, southeast corner
ISU3	1st floor, east open office space	ISU12	2nd floor, east open office space and conference room
ISU4	1st floor, restrooms	ISU13	2nd floor, maintenance/storage/copier/elevator rooms
ISU5	Stairwell from 1st to 2nd floor	ISU14	2nd floor, restrooms
ISU6	1st floor, corridor from south entrance to northern office area	ISU15	2nd floor, corridor form south to main entrance
ISU7	1st floor, maintenance/mechanical/elevator rooms	ISU16	2nd floor, southwest corner
ISU8	1st floor, southwest corner	ISU17	2nd floor, northwest corner
ISU9	1st floor, northwest corner	ISU 18	2nd floor

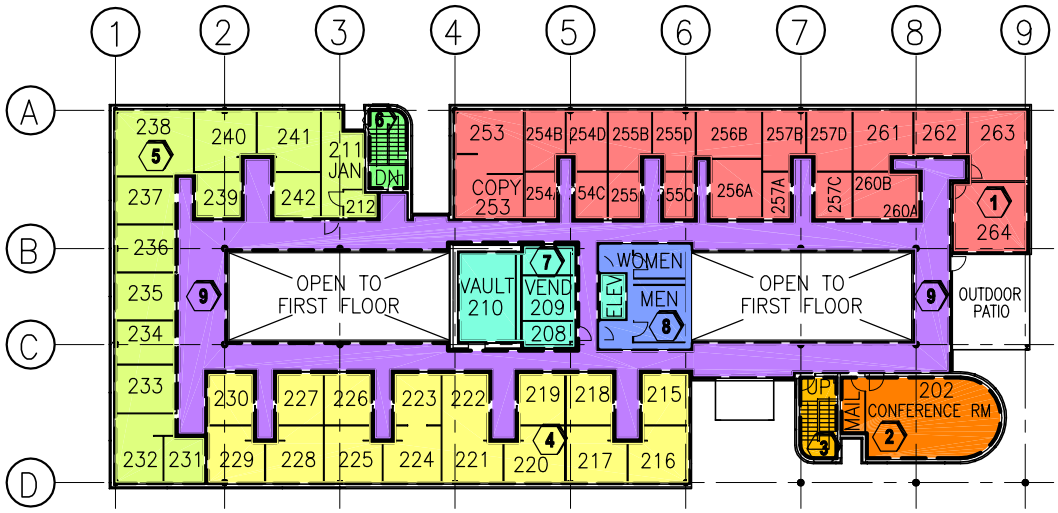
Data for each aggregate were summarized and statistical indicators were computed. The exposure concentration used in the risk calculation was either the computed 95% upper confidence limit (UCL95) of the mean or the maximum detection, whichever was smaller. Only detected values were considered in the calculation of the exposure concentration. In the case of ISUs where qualifiers were not available, it was assumed that values of zero, or negative values, were non-detects and all other values were detects.

In addition to the removable and fixed contamination sampling, measurements were made to determine external dose rates for the building interior. The dose rate data were used to estimate the dose to a hypothetical exposed individual.

[3]Note: Figure 4.1 shows ISU 10 as Rooms 109A and 101. However, the building contains only one room in this space, which is labeled Room 100. This room was surveyed as ISU 10.

K-1225 FIRST FLOOR PLAN

SCALE: 1" = 40'-0"



K-1225 SECOND FLOOR PLAN

SCALE: 1" = 40'-0"

LEGEND:

- SURVEY UNIT 1
- SURVEY UNIT 2
- SURVEY UNIT 3
- SURVEY UNIT 4
- SURVEY UNIT 5
- SURVEY UNIT 6
- SURVEY UNIT 7
- SURVEY UNIT 8
- SURVEY UNIT 9
- SURVEY UNIT 10
- SURVEY UNIT 11
- (2) SURVEY UNIT NUMBER

5.39°± ETTP GRID TRUE NORTH

0 20 40

SCALE: 1" = 40'

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Fig. 4.1. K-1225 first and second interior survey units.

For this risk screen, it was necessary to convert the general survey measurements of beta/gamma activity [in units of disintegrations per minute per 100 square centimeters (dpm/100 cm^2)] into isotopic concentrations [in units of picocuries per gram (pCi/g)]. Conversion of the overall beta/gamma measurements taken from the interior of the building to isotopic concentrations for use in risk assessment requires application of beta/isotope ratios. The most applicable investigation of beta/isotope ratios available is an evaluation of Bldg. K-1401, which included a comparison of isotope-specific measurements with gross beta measurements from the building interior (Rucker 1998). Ratios of isotopic activity to gross beta activity were established for use in dose and risk assessment for 11 isotopes, including several thorium isotopes of interest to the risk assessment. The Bldg. K-1401 study was conducted specifically to generate beta/isotope ratios and considered a comprehensive list of isotopes. Additionally, the K-1401 building was used for a range of activities and processes that generally represent those activities and processes that took place at ETTP as a whole. Therefore, the risk assessment for Bldg. K-1225 assumes that the large room average results of the K-1401 investigation, presented in Table 4.2, are considered representative of the isotopic activity to beta activity ratios found in the interior of Bldg. K-1225. The resulting isotopic concentrations in dpm/100cm^2 were converted into units of pCi/g assuming a material density of 1.5 grams/cubic centimeter, a material depth of 0.1 cm, and a conversion factor of 2.22 pCi/dpm.

Table 4.2. Isotopic activity ratios

Isotope	Ratio to[a] total beta activity
Am-241	5.70E-04
Np-237+D	2.20E-03
Pu-238	2.10E-04
Pu-239	1.70E-03
Tc-99	6.60E-01
Th-228+D	2.00E-03
Th-230	6.20E-03
Th-232	1.90E-03
U-234	2.70E-01
U-235+D	2.60E-02
U-238+D	1.60E-01

[a]Values reported in Rucker 1998.

Interior Survey Results

All total activities for ISUs were less than 89 dpm/100 cm^2 total alpha and 883 dpm/100 cm^2 total beta-gamma, with all removable contamination results less than 8.1 dpm/100 cm^2 removable alpha and 41.6 dpm/100 cm^2 removable beta-gamma. The maximum tissue-equivalent dose rate was 8 microrem/h (μrem/h).

Furnishings Survey Results

Activities for FSUs were less than 136 dpm/100 cm^2 total alpha and 514 dpm/100 cm^2 total beta-gamma, with all removable contamination results less than 5.4 dpm/100 cm^2 removable alpha and 30.5 dpm/100 cm^2 removable beta-gamma.

Exterior Survey Results

All total activities were less than 187 dpm/100 cm^2 total alpha and 1552 dpm/100 cm^2 total beta-gamma, with all removable contamination results less than 11 dpm/100 cm^2 removable alpha (from a QA/QC measurement) and 45 dpm/100 cm^2 removable beta-gamma. The maximum tissue-equivalent dose rate was 6 μrem/h.

5. EXPOSURE ASSESSMENT

An exposure assessment combines information about site characteristics and site-related data with exposure assumptions in order to quantify the intake of contaminants by a hypothetically exposed individual. The estimated exposure is based on:

- characterizing the exposure scenario based on site surveys and anticipated future building use,
- identifying complete exposure pathways based on assumed receptor activities and site-specific information, and
- quantifying receptor exposure based on exposure assumptions and chemical-specific data.

The steps in the exposure assessment are discussed in detail in the following sections.

5.1 EXPOSURE SCENARIO EVALUATION

5.1.1 Industrial Worker Scenario

Exposure scenarios are selected based on site surveys and anticipated uses of Bldg. K-1225. The ETTP area is being transferred for industrial uses ranging from light to heavy industrial applications. Because the K-1225 building has been used in the past for office space, it is unlikely that heavy industrial activities would be compatible with the building infrastructure. Therefore, the anticipated building use scenario is for office use up to light industrial activity, represented by an industrial worker exposure scenario in this evaluation. Exposures to the building worker while spending time outside the building were included in the roving worker exposure scenario (see Sect. 5.1.2).

The exposure scenario for this evaluation is based on an industrial worker who may be present in the interior of Bldg. K-1225 performing administrative or basic industrial activities during the workday. The industrial worker exposure scenario assumes the following:

- the industrial worker is employed at Bldg. K-1225 for a 25-year period,
- the worker is on-site for 250 d/year, and
- the worker spends the entire 8-h day working in the interior of Bldg. K-1225.

An industrial worker is assumed to spend every workday, for the entire workday, in a single ISU. Although it is unlikely a worker would be limited to such a small area of the building, this assumption is intended to overestimate potential exposures and provide a conservative estimate of the associated risks.

There is the possibility that an industrial worker would circulate throughout Bldg. K-1225 either in a supervisory or maintenance role. In that case, an average of the exposures for the individual survey units would be more representative of the potential risks or doses for the building as a whole. A risk estimate based on the average exposure throughout the building interior and representing a roaming receptor is presented in the summary tables for comparison to the risk estimate for a non-roaming receptor.

5.1.2 Roving Worker Scenario

In addition to the 8-h working day spent in the interior of the K-1225 building, it is assumed that the worker spends an additional amount of time outdoors at the plant site. To address the potential for exposure outside of a title transfer area, it was assumed that an industrial worker might spend 2 h each day in accessible areas of ETTP (including locations in both Zones 1 and 2) [see Fig. 5.1]. A roving worker might spend this time by walking throughout areas in the vicinity of ETTP and being exposed to contaminated media. Exposure units (EUs) that could reasonably be accessed were selected based on the location of existing fencing and access controls.

Areas were eliminated if they were within security fencing (to which the rover cannot gain access) or were located at a distance that could not be reasonably accessed on a frequent basis. The relevance of specific datasets was also a criterion in the selection of EUs for the evaluation. As an example, EU Z2-27, in the Mitchell Branch area, was represented only by sediment sample data and was eliminated since exposure to sediment was considered unlikely. Figure 5.1 presents all of the EUs designated in Zones 1 and 2 at ETTP and highlights the EUs selected for this roving worker evaluation.

The boundaries for Zone 1 EUs were created for the *Record of Decision for Interim Actions in Zone 1, East Tennessee Technology Park, Oak Ridge, Tennessee* (DOE 2002a). The boundaries for the Zone 2 EUs were created for the *Focused Feasibility Study for Zone 2 at the East Tennessee Technology Park, Oak Ridge, Tennessee* (BJC in progress). It is assumed that the roving worker spends an equal amount of time in each of the areas considered accessible and may be exposed to surface soil during each period of roving. Therefore, the aggregate of soil data with starting depths no deeper than 2 ft from all accessible areas outside/inside the main plant fence was considered a representative dataset for the roving worker exposure scenario evaluation.

The roving building worker scenario applies to a worker who works at ETTP for a 25-year period. The risk calculations for the roving worker assumed that ETTP will be remediated to levels protective of human health by the year 2008 in accordance with the *Oak Ridge Performance Management Plan* (DOE 2002b). The roving worker would, therefore, be exposed to contaminated soil for a 5-year period (i.e., 2003 to 2008) and to acceptably clean soil [as designated by the Record of Decision (ROD)] for the remaining 20-year working lifetime. Therefore, rover is assumed to spend a 2-h period each day roaming the accessible areas of ETTP, for 250 d each year for 5 years.

5.2 EXPOSURE PATHWAY IDENTIFICATION

Evaluating the exposure pathways requires describing the mechanism by which an individual may become exposed to contaminants associated with Bldg. K-1225. A complete exposure pathway requires the following:

- a source of contamination,
- a pathway of migration from the source of contamination to the exposure point,
- a receptor present at the exposure point, and
- an exposure mechanism at the exposure point.

If any one component of a complete exposure pathway is missing, then the pathway is considered incomplete. Only complete exposure pathways were quantified in the risk screen.

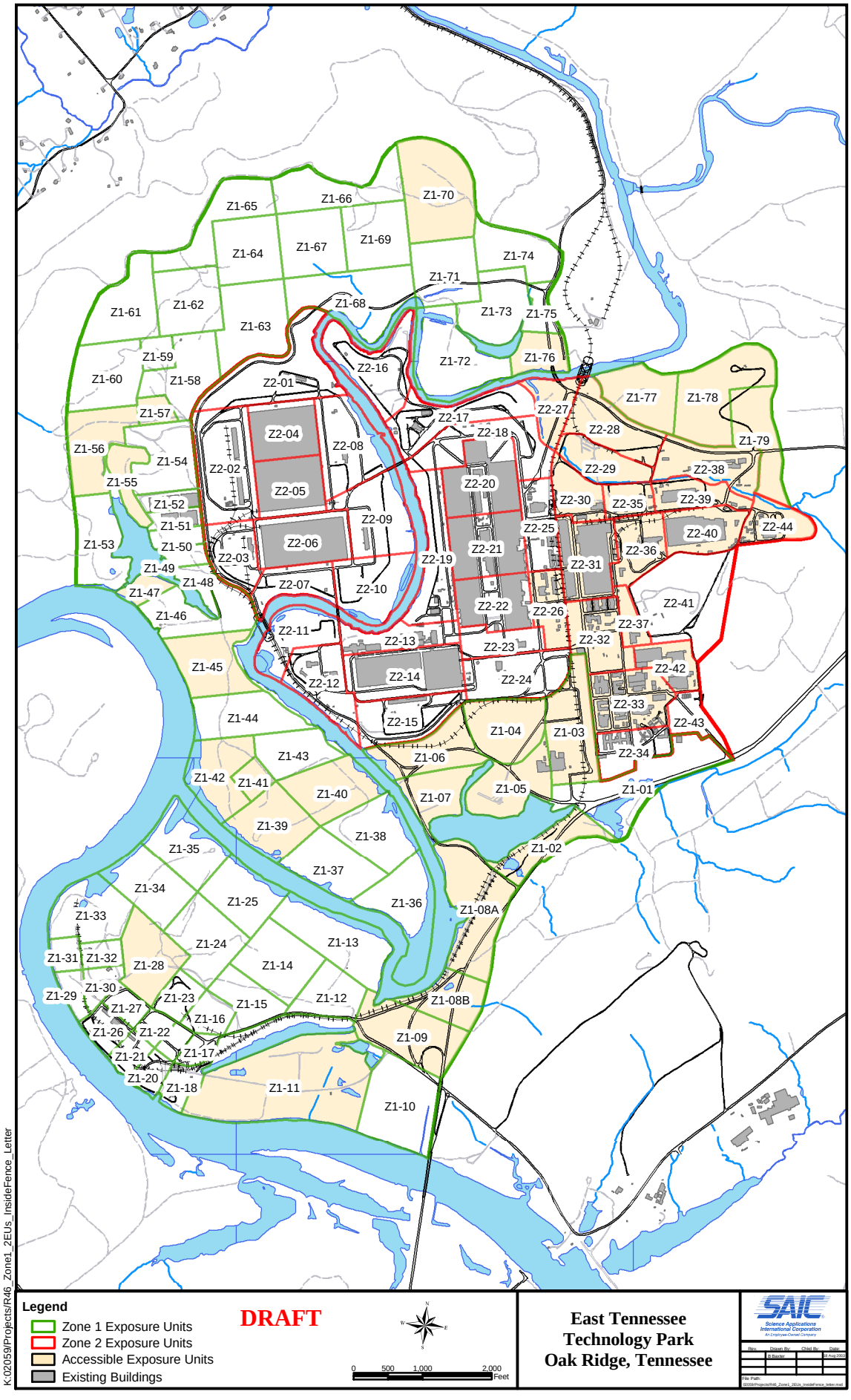

Fig. 5.1. Zone 1 and 2 Exposure Units accessible to the roving worker inside the main plant fence.

Complete exposure pathways associated with Bldg. K-1225 include ingestion, inhalation, and external exposure to ionizing radiation. The ingestion pathway is complete because contaminated surfaces may be present, a receptor is present in the building, and a receptor may contact and ingest contaminants from the building surfaces. The inhalation pathway is complete because contaminated surfaces may be present, contaminants may become airborne during normal industrial activities, a receptor is present in the building, and a worker may inhale contaminants in the air. External exposure to ionizing radiation is a complete exposure pathway because radionuclides may be present on the building surfaces, ionizing radiation may be emitted, and a receptor is present to absorb the radiation. Potential exposure pathways for the roving worker include inhalation of suspended dust and volatile organics, ingestion of soil, dermal contact with soil, and external exposure to ionizing radiation from soil. The following section describes how each of these exposure pathways was quantified in the risk screen.

5.3 QUANTIFICATION OF EXPOSURE

Quantifying the exposure to the receptor requires:

- identification of the exposure concentration at the receptor exposure point,
- estimation of exposure parameters appropriate to the exposed individual, and
- calculation of the receptor exposure.

The purpose of the quantification of exposures is to provide a conservative estimate of exposures related to the exposure scenarios evaluated. At each step in the quantification process, assumptions are made in a conservative manner in an attempt to overestimate the risks/hazards and provide an upper bound estimate of risk that is protective of future workers in the building.

5.3.1 Industrial Worker

The ingestion and inhalation pathways were quantified using the sampling data for removable contamination, as well as fixed contamination. For the industrial worker exposure scenario, it was assumed that 100% of the detected removable contamination is available for ingestion each workday, and 100% of the detected removable contamination is available for inhalation each workday. In this scenario, there is no depletion of the source material over the working lifetime of the industrial worker. This is a conservative assumption that is evaluated because the anticipated industrial worker could contact the interior wall and ceiling surface over the course of normal activities.

The industrial worker scenario does not consider any renovation work; therefore, it is unlikely that any fixed contamination would be disturbed and be removed in any significant quantities. However, to provide greater conservatism in the risk screen for Bldg. K-1225, it was also assumed that some portion of the detected fixed contamination in each survey unit could be mobilized and become available for ingestion and inhalation.

An estimate of the amount of fixed contamination that could become removable was based on an evaluation of the ISU data. The percent of removable contamination to fixed contamination, based on the calculated exposure concentrations for smear and total data, respectively, ranged from 5% in ISU 17 to ~10% for ISU 7 and averaged ~ 8% for all 18 units. Therefore, for conservatism, the risk associated with ingestion and inhalation is assumed to be 10% of the fixed contamination and was also included in the evaluation of survey units that showed detectable levels of removable contamination. The Nuclear Regulatory Commission Decontamination and Demolition Code recommends the use of 10% removable unless data specify a higher number. In addition, the use of 10% has been negotiated with the Tennessee Department of Environment and Conservation. All of the 18 ISUs had detectable removable contamination. As a result, all 18 ISUs were evaluated assuming that 100% of removable contamination and 10% of fixed contamination were available for industrial worker exposure.

External dose measurements (mrem/h) were used to quantify potential external exposure. The measurements were generally collected at areas of highest readings in the building interior. The UCL95 of the mean of the dose rate data was calculated to be ~0.005 mrem/h, which is below the background level of 0.007 mrem/h. Therefore, the risks due to external exposure were not quantified.

Quantifying the exposure requires an estimate of the exposure parameters for the exposed individual. The industrial worker exposure scenario assumes the following:

- the industrial worker is employed at Bldg. K-1225 for a 25-year period (EPA 1989 default),
- the worker is on-site for 250 d/year (EPA 1989 default),
- the worker spends 8 h/d in the interior of Bldg. K-1225 (site-specific assumption),
- the worker ingests 50 mg of contaminated material each day (EPA 1989 default), and
- the worker inhales 20 m^3 of air each day (EPA 1989 default).

Two scenarios were evaluated:

1. The industrial worker is assumed to spend every workday, for the entire workday, in a single ISU. Although it is unlikely a worker would be limited to such a small area of the building, this assumption is intended to overestimate potential exposures and provide a conservative estimate of the associated risks.

2. The industrial worker is assumed to spend every workday spending equal amounts of time in all ISUs, and, thus, the exposure is an average of exposure in all the ISUs.

5.3.2 Roving Worker

Quantifying the exposure requires an estimate of the exposure parameters for the exposed individual. The roving worker exposure scenario assumes the following:

- beginning in 2003, the roving industrial worker may access contaminated soil for 5 years, until 2008 when remediation will be completed at ETTP;

- the roving worker is on-site for 250 d/year;

- the roving worker spends 2 h each day wandering ETTP among all accessible EUs;

- the roving worker ingests 50 mg of contaminated soil during each 2-h period of wandering; and

- the roving worker inhales 20 m^3 of air during each 2-h period of wandering.

The assumptions of 50 mg of soil ingested and 20 m^3 of air inhaled are generally used when considering exposure for an entire day. However, based on direction from EPA Region 4, these assumptions will not be reduced even though the exposure is only for 2 h each day. Using these parameters for a 2-h period will overestimate the actual risks to a roving worker and provide an upper bound estimate of the associated risks. (For more detail, see Appendix A.)

The quantification of receptor exposure forms the basis of the risk calculation. In the risk calculation step, the receptor exposure is compared to benchmark values to determine the probability of adverse health effects. The resulting risk calculations are presented in Appendix A.

6. RISK RESULTS

6.1 INDUSTRIAL WORKER

Building K-1225 risks were calculated for the industrial worker scenario assuming exposure by the inhalation, ingestion, and external exposure pathways. Table 6.1 presents the risks and doses from exposure to ISUs in Bldg. K-1225. The table shows that all ISUs had risks on the order of 10^{-8}. The conservative assumption that 10% of the fixed contamination would become removable contributed to the majority of the risk, accounting for approximately one and a third times the risk of the removable contamination.

The risk estimate is a value that represents the excess cancer incidence that might be expected due to the exposure scenario evaluated. The EPA has established a target risk range of 10^{-4} to 10^{-6}. The estimated risk of 4×10^{-8} for Bldg. K-1225 is within the EPA target range, indicating a low likelihood of adverse health effects due to the exposure scenarios considered.

The Bldg. K-1225 calculated doses indicated a maximum of ~0.004 mrem/year due to ingestion and inhalation of removable and fixed contamination in ISU9. The calculated average dose for Bldg. K-1225 was ~ 0.003 mrem/year with 10% of the total activity accounting for approximately one and a third times the dose from the removable contamination. For comparison, the average dose due to ambient sources (medical X-rays, cosmic rays, natural materials, etc.) is approximately 360 mrem/year (National Council on Radiation Protection and Measurements 1987). The dose from the measured background dose rate for ETTP of 0.007 mrem/h is equivalent to ~ 60 mrem/year assuming 24 h/d and 365 d/year exposure. The calculated doses are significantly below both measures of background dose for Bldg. K-1225.

The risks associated with an industrial worker at Bldg. K-1225 can be summarized as follows:

- the maximum risk associated with an individual survey unit was 6×10^{-8} for ISU 9 (see bolded text in Table 6.1), the hallways on the second floor;
- the maximum calculated dose was ~ 0.004 mrem/year for ISU 9 (see bolded text in Table 6.1), the hallways on the second floor;
- the UCL95 of the mean of the dose rate data was calculated to be ~0.005 mrem/h, which is below the site background level of 0.007 mrem/h;
- the average risk associated with the interior of Bldg. K-1225 was 4×10^{-8}, assuming a receptor is equally exposed to all interior survey areas; and
- the average calculated dose associated with the interior of Bldg. K-1225 was ~ 0.003 mrem/year for the interior of the building as a whole.

Table 6.1. Carcinogenic risk and radiological dose estimates for K-1225 interior and furnishings[a]

Carcinogenic risk (risk/lifetime)	Removable activity			10% of total activity			
Interior survey unit	Ingestion risk	Inhalation risk	Total	Ingestion risk	Inhalation risk	Total	Overall total
ISU1	1.91E-08	8.72E-11	1.92E-08	2.07E-08	9.45E-11	2.08E-08	4.01E-08
ISU2	2.03E-08	9.23E-11	2.03E-08	2.29E-08	1.04E-10	2.30E-08	4.33E-08
ISU3	2.00E-08	9.13E-11	2.01E-08	2.29E-08	1.04E-10	2.30E-08	4.31E-08
ISU4	1.32E-08	6.03E-11	1.33E-08	1.98E-08	9.02E-11	1.99E-08	3.32E-08
ISU5	1.36E-08	6.21E-11	1.37E-08	2.20E-08	1.00E-10	2.21E-08	3.57E-08
ISU6	1.76E-08	8.00E-11	1.76E-08	2.02E-08	9.21E-11	2.03E-08	3.79E-08
ISU7	2.15E-08	9.80E-11	2.16E-08	2.13E-08	9.73E-11	2.14E-08	4.30E-08
ISU8	1.71E-08	7.80E-11	1.72E-08	2.59E-08	1.18E-10	2.60E-08	4.32E-08
ISU9	1.71E-08	7.79E-11	1.72E-08	3.64E-08	1.66E-10	3.66E-08	**5.37E-08**
ISU10	1.65E-08	7.51E-11	1.66E-08	1.93E-08	8.80E-11	1.94E-08	3.60E-08
ISU11	2.01E-08	9.15E-11	2.02E-08	2.47E-08	1.13E-10	2.48E-08	4.50E-08
ISU12	1.71E-08	7.78E-11	1.71E-08	2.40E-08	1.09E-10	2.41E-08	4.12E-08
ISU13	1.83E-08	8.33E-11	1.84E-08	1.83E-08	8.33E-11	1.83E-08	3.67E-08
ISU14	1.68E-08	7.65E-11	1.69E-08	2.53E-08	1.16E-10	2.55E-08	4.23E-08
ISU15	1.65E-08	7.52E-11	1.66E-08	2.18E-08	9.93E-11	2.19E-08	3.85E-08
ISU16	1.47E-08	6.70E-11	1.48E-08	2.00E-08	9.11E-11	2.01E-08	3.48E-08
ISU17	1.66E-08	7.56E-11	1.67E-08	3.04E-08	1.39E-10	3.06E-08	4.72E-08
ISU18	1.46E-08	6.64E-11	1.46E-08	1.63E-08	7.42E-11	1.64E-08	3.10E-08
Average[b]	1.73E-08	7.86E-11	1.73E-08	2.29E-08	1.04E-10	2.30E-08	4.03E-08
Radiological dose (mrem/year)	**Removable activity**			**10% of total activity**			
Interior survey unit	**Ingestion dose**	**Inhalation dose**	**Total dose**	**Ingestion dose**	**Inhalation dose**	**Total dose**	**Overall total**
ISU1	1.32E-03	6.48E-06	1.33E-03	1.43E-03	7.02E-06	1.44E-03	2.77E-03
ISU2	1.40E-03	6.86E-06	1.41E-03	1.58E-03	7.74E-06	1.59E-03	3.00E-03
ISU3	1.39E-03	6.78E-06	1.39E-03	1.58E-03	7.74E-06	1.59E-03	2.98E-03
ISU4	9.15E-04	4.48E-06	9.19E-04	1.37E-03	6.70E-06	1.37E-03	2.29E-03
ISU5	9.42E-04	4.61E-06	9.46E-04	1.52E-03	7.43E-06	1.53E-03	2.47E-03
ISU6	1.21E-03	5.94E-06	1.22E-03	1.40E-03	6.84E-06	1.40E-03	2.62E-03
ISU7	1.49E-03	7.28E-06	1.49E-03	1.48E-03	7.22E-06	1.48E-03	2.98E-03
ISU8	1.18E-03	5.79E-06	1.19E-03	1.79E-03	8.77E-06	1.80E-03	2.99E-03
ISU9	1.18E-03	5.78E-06	1.19E-03	2.52E-03	1.23E-05	2.53E-03	**3.72E-03**
ISU10	1.14E-03	5.58E-06	1.15E-03	1.34E-03	6.54E-06	1.34E-03	2.49E-03
ISU11	1.39E-03	6.80E-06	1.40E-03	1.71E-03	8.37E-06	1.72E-03	3.11E-03
ISU12	1.18E-03	5.78E-06	1.19E-03	1.66E-03	8.11E-06	1.67E-03	2.85E-03
ISU13	1.26E-03	6.19E-06	1.27E-03	1.26E-03	6.18E-06	1.27E-03	2.54E-03
ISU14	1.16E-03	5.68E-06	1.17E-03	1.75E-03	8.58E-06	1.76E-03	2.93E-03

Table 6.1. Carcinogenic risk and radiological dose estimates for K-1225 interior and furnishings[a] (continued)

Radiological dose (mrem/year)	Removable activity			10% of total activity			
Interior survey unit	Ingestion dose	Inhalation dose	Total dose	Ingestion dose	Inhalation dose	Total dose	Overall total
ISU15	1.14E-03	5.58E-06	1.15E-03	1.51E-03	7.37E-06	1.51E-03	2.66E-03
ISU16	1.02E-03	4.97E-06	1.02E-03	1.38E-03	6.77E-06	1.39E-03	2.41E-03
ISU17	1.15E-03	5.61E-06	1.15E-03	2.11E-03	1.03E-05	2.12E-03	3.27E-03
ISU18	1.01E-03	4.93E-06	1.01E-03	1.13E-03	5.51E-06	1.13E-03	2.14E-03
Average[b]	1.19E-03	5.84E-06	1.20E-03	1.58E-03	7.75E-06	1.59E-03	2.79E-03

[a]Uses exposure concentration = lesser of max and 95% upper confidence limit of the mean (UCL95) [UCL95 may be larger than max if data are limited]. Only survey units with detected removable activity were included in the assessment.

[b]Assumes receptor is equally exposed to each interior survey unit throughout the workday.

[c]**Bold** indicates maximum risk/dose.

6.2 ROVING WORKER

The roving worker risk assessment considered quantitatively 45 surface soil COPCs (14 metals, 16 organics, and 15 radionuclides) for the accessible areas of ETTP. The risk to the roving worker was 2×10^{-5}, which is within the EPA acceptable range of 10^{-4} to 10^{-6}. The risk was mainly due to external exposure to ionizing radiation, as well as both ingestion and dermal contact with polycyclic aromatic hydrocarbons. The calculated hazard for the roving worker was 0.3, which is below the EPA acceptable level of 1.0. For additional information, see Appendix A.

6.3 RISK SUMMARY

The risk evaluation for Bldg. K-1225 indicates that all risks, doses, and hazards are considered within acceptable levels of EPA's target risk range, (see Table 6.2) which correlates with a low likelihood of adverse health effects to an industrial worker. Therefore, the facility is considered acceptable for transfer for its intended use as an office building by the private sector.

Table 6.2. Summary of risks/hazards for Building K-1225

Receptor	Hazard	Risk
Industrial worker		
Maximum ISU	N/A	6×10^{-8}
Average for all ISUs	N/A	4×10^{-8}
Roving worker	0.3	2×10^{-5}
Total	**0.3**	$\mathbf{2 \times 10^{-5}}$

ISU = interior survey unit.
N/A = not applicable.

7. EVALUATION OF UNCERTAINTIES

The estimation of uncertainty, whether quantitative or qualitative, is fundamental to scientific activities that involve measured or assessed quantities. Estimates of risk are conditional based on a number of assumptions concerning exposure. In cases where probabilistic estimates are generated [i.e., central tendencies (expected risks) and associated high-end exposure with probability of occurrence], the impact of the variation in assumptions on the risk estimate can be identified. Generation of a point estimate of risk, as has been done in this screening-level assessment, has the potential to yield under- or overestimates of the actual value and can lead to improper decisions. Therefore, it is necessary to specify the assumptions and uncertainties inherent in the screening-level evaluation process to place the risk estimates in perspective and ensure that anyone making risk management decisions is well informed.

Uncertainty about environmental risk estimates is known to be at least an order of magnitude or greater (EPA 1989). The evaluation of uncertainties for the assessment is qualitative since the resource requirements necessary to provide a quantitative statistical uncertainty analysis for this study area would generally outweigh the benefits. The focus of the discussion in this section will be on the important variables and assumptions that contribute most to the overall uncertainty.

7.1 UNCERTAINTY IN THE SOURCE TERM

Several uncertainties are associated with the data set and the data evaluation process. These uncertainties include the selection of COPCs and the determination of the exposure point concentration.

Although the data evaluation process used to select COPCs adheres to established procedures and guidance, it also requires making decisions and developing assumptions on the basis of historical information, process knowledge, and best professional judgment about the data. Uncertainties are associated with all such assumptions. The background concentrations and preliminary remediation goals (PRGs) used to screen analytes are also subject to uncertainty. The toxicity values used in the derivation of PRGs are subject to change, as additional information (from scientific research) becomes available; these periodic changes in toxicity values may cause the PRG values to change as well, causing increased uncertainty in the data screening process.

Representative concentrations and other statistics are calculated in this risk assessment based on the assumption that the samples collected are truly random samples. Some of the data may not have been taken randomly, but rather may have come from biased sampling, aimed at identifying high contaminant concentration locations. In addition, the soil data used for the rover scenario come from multiple sampling events conducted in multiple years and are not necessarily representative of current conditions. Concentrations of constituents may be lower and, hence, the risks/hazards may be lower than what is reported here.

This evaluation has been performed using only the COPCs with available toxicity data. It should be noted that the qualitative COPCs determined for this study area could potentially increase the risks/hazards to a receptor.

As noted in Chap. 3 of this report, the potential contribution of vapor intrusion has not been evaluated. If vapor intrusion is a complete pathway, and concentrations are high enough, risks/hazards reported here may be underestimated.

7.2 UNCERTAINTY IN THE EXPOSURE ASSESSMENT

For each exposure pathway, assumptions are made concerning the parameters, the routes of exposure, the amount of contaminated media an individual can be exposed to, and intake rates for different routes of exposure. In the absence of site-specific data, the assumptions used in this assessment are consistent with EPA-approved parameters and default values. When several of these upper-bound values are combined in estimating exposure for any one pathway, the resulting risks can be in excess of the 99th percentile and, therefore, outside the range that may be reasonably expected. It has been assumed that the worker ingests 50 mg of dust inside the building and an additional 50 mg of soil outdoors while roving. The total ingestion of 100 mg is conservative and may produce an overestimation of the risks/hazards.

The assumptions of 50 mg of soil ingested and 20 m^3 of air inhaled are generally used when considering exposure for an entire day. However, based on direction from Region 4 of EPA, these assumptions will not be reduced even though the exposure is only for 2 h each day. Using these parameters for a 2-h period will overestimate the actual risks to a roving worker and provide an upper-bound estimate of the associated risks.

The guidance values for intake rates and exposure parameters are assumed to be representative of the hypothetical populations evaluated. All contaminant exposures and intakes are assumed to be from the site-related exposure media (i.e., no other sources contribute to the receptor's risk). Even if these assumptions are true, other areas of uncertainty may apply. Selected intake rates and population characteristics (i.e., weight, life span, and activities) are assumed to be representative of the exposed population. The consistent conservatism used in the estimation of these parameters generally leads to overestimation of the potential risk to the postulated receptors.

7.3 UNCERTAINTY IN TOXICITY VALUES AND RISK PREDICTIONS

Uncertainty in the values used to represent the dose-response relationship will highly impact the risk estimates. These uncertainties are contaminant specific and are embedded in the toxicity value. The factors that are incorporated to represent sources of uncertainty include the source of the data, duration of the study, extrapolations from short- to long-term exposures, intrahuman or interspecies variability, and other special considerations. In addition, toxicity varies with the chemical form.

Uncertainties related to the summation of carcinogenic risk and non-carcinogenic hazard estimates across contaminants and pathways are a primary uncertainty in the risk characterization process. In the absence of information on the toxicity of specific chemical mixtures, additive (cumulative) risks are assumed (EPA 1989).

Limitations of the additive risk approach for exposure to multiple chemicals include:

1. the slope factors may represent the mean but often represent the upper 95th percentile estimate of potency (the central estimate of the mean for radionuclides), so the summation can result in an excessively conservative estimate of lifetime risk;

2. the reference doses do not have equal accuracy or precision and are not based on the same severity of effects; and

3. the effects of a mixture of carcinogens are unknown, and possible interactions could be synergistic or antagonistic.

Despite these limitations and the general unavailability of data on these interactions, summations were performed for the carcinogenic risks and chemical hazards presented in risk assessment. This approach is consistent with *Risk Assessment Guidance Superfund* (EPA 1989).

8. REFERENCES

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APPENDIX A

ROVING WORKER SCENARIO FOR TITLE TRANSFER FACILITIES LOCATED INSIDE THE MAIN PLANT AREA AT THE EAST TENNESSEE TECHNOLOGY PARK

CONTENTS

FIGURE

TABLES

A.1. INTRODUCTION

In order to address potential risks from areas that are not in the immediate vicinity of the facility, but could reasonably be accessible to the occupant, a roving worker (or "rover"), who may move within East Tennessee Technology Park (ETTP) areas that do not have access restrictions (i.e., security portals or gates) for a general worker, has been evaluated.

The areas accessible to the "rover" are based on the location of the title transfer area. The overall risk for a building worker will be calculated by adding the risks from the building to the risk calculated for areas accessible to the "rover" where applicable. The roving worker scenario for areas accessible inside the main plant area is described in detail in the following sections. (This scenario is also referred to as the "inside rover.")

A.2. EXPOSURE SCENARIO EVALUATION

It was assumed that a building worker might spend 2 h each day accessing areas of ETTP that are near his/her place of business. A roving worker might spend this time by walking throughout fenced and unfenced areas in the vicinity of ETTP and being exposed to contaminated media. Identification of the specific areas accessed by the "rover" was based on an evaluation of ETTP exposure units (EUs), which were previously delineated for risk assessment purposes. EUs that could reasonably be accessed by a general plant worker were selected based on the location of existing security fencing and access controls.

Areas were eliminated if they were within security fencing or were located at a distance that could not be reasonably accessed on a frequent basis. For example, data from sampling points within a security fence southeast of Blair Road (in EU Z2-28) were eliminated from the evaluation because they are inaccessible to a general worker. The relevance of specific datasets was also a criterion in the selection of EUs for the evaluation. As an example, EU Z2-27, in the Mitchell Branch area, was represented only by sediment sample data and was eliminated since exposure to sediment was considered unlikely. Figure A.1 presents all of the EUs designated in Zones 1 and 2 at ETTP and highlights the EUs selected for this roving worker evaluation.

Remediation at ETTP is scheduled to be completed by the year 2008. It was, therefore, assumed that exposure to exterior soils would be of a limited duration of 5 years (2003 through 2008). It was also assumed that a roving worker would be exposed to soils for 2 h on each of the 250 workdays each year. It is unlikely that an individual would spend such an extensive amount of time outdoors in a single area. Therefore, it was assumed that a roving worker might spend equal amounts of time traveling among all of the accessible EUs. This scenario would represent a worker who exercises and/or eats lunch at different locations at the site. Although conservative, this approach is considered more realistic than the alternative of assuming that a "rover" spends all of his time in one location. For these reasons, the rover that is exposed to all EUs is the preferred scenario.

A.3. EXPOSURE PATHWAY IDENTIFICATION

Complete exposure pathways for the roving worker include ingestion, inhalation, dermal contact, and external exposure.

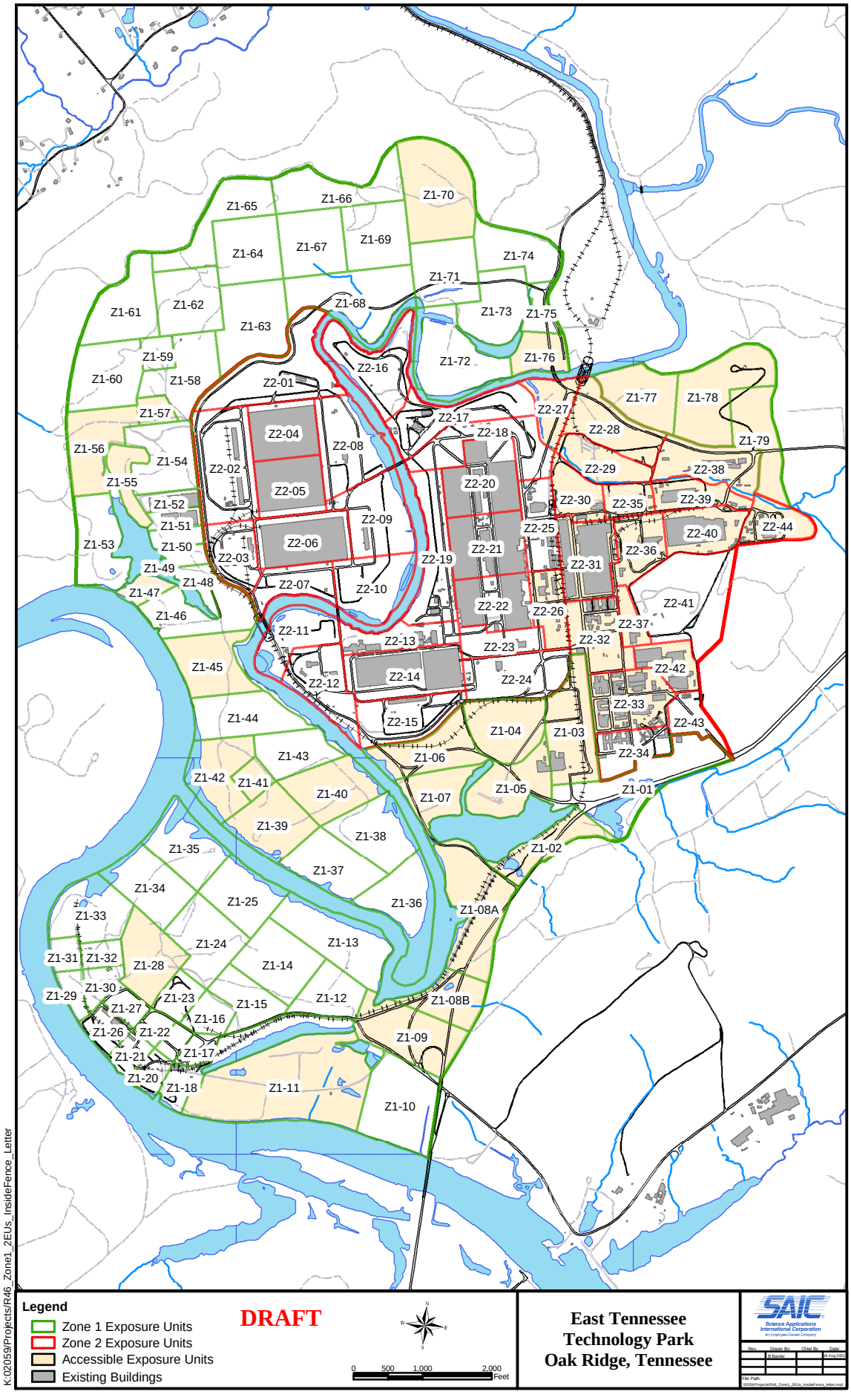

Fig. A.1. Zone 1 and 2 Exposure Units accessible to the roving worker inside the main plant fence.

The ingestion pathway is complete because:

- contaminated media are present in EUs,
- a worker could be present in EUs, and
- a worker could inadvertently ingest media while spending time in EUs.

The inhalation pathway is complete because:

- contaminated media are present in EUs,
- the media may become airborne due to volatilization or dust resuspension,
- a worker could be present in EUs, and
- a worker could inhale some contaminated media while spending time in EUs.

The dermal pathway is complete because:

- contaminated media are present in EUs,
- a worker could be present in EUs, and
- a worker could inadvertently come into contact with contaminated media while spending time in the area.

External exposure to ionizing radiation is a complete exposure pathway because:

- radionuclides may be present in EUs media,
- ionizing radiation could be emitted, and
- a worker could be present in EUs to absorb emitted radiation.

The quantification of each of these exposure pathways is described in the following sections.

A.4. QUANTIFICATION OF EXPOSURE

Quantifying the exposure to the receptor requires:

- statistical evaluation of the representative dataset (Table A.1);
- selection of contaminants of potential concern (COPCs), based on comparison to background concentrations and preliminary remediation goals (PRGs) [Table A.2];
- identification of the COPCs that have available toxicity data and can be quantitatively evaluated (Table A.3);
- estimation of the exposure parameters appropriate to the roving worker (Table A.4);
- selection of toxicity data appropriate for the receptor and exposure pathways (Table A.5); and
- calculation of the intake, risks, and hazards to the roving worker (Tables A.6 and A.7) based on the calculated exposure concentrations.

The ingestion, inhalation, dermal contact, and external exposure pathways were quantified using available soil and radiological survey data for the accessible EU areas.

The list of COPCs was identified for the aggregated data representing all accessible EUs, based on comparison to PRGs and background concentrations. [Note: There have been discussions regarding the use of background data, and U. S. Environmental Protection Agency (EPA)- and U. S. Department of Energy-negotiated the current data set. EM has agreed to collect a new data set. However, until the new background data are available, the negotiated background data will be used.] Exposure concentrations for the COPCs represent the expected concentration the roving worker will encounter in soil and are typically the 95% upper confidence limit of the mean (UCL95) detected concentration or the maximum detected concentration, whichever is smaller. Exposure concentrations, the basis for the quantification of risk, were calculated from the aggregated data for all accessible EUs.

Quantifying the exposure requires an estimate of the exposure parameters for the individual. The roving worker exposure scenario assumes the following:

- beginning in 2003, the roving industrial worker may access contaminated soil for 5 years, until 2008 when remediation will be completed at ETTP;
- the roving worker is on-site for 250 d/year;
- the roving worker spends 2 h each day wandering ETTP among all accessible EUs;
- the roving worker ingests 50 mg of contaminated soil during each 2-h period of wandering; and
- the roving worker inhales 20 m^3 of air during each 2-h period of wandering.

The assumptions of 50 mg of soil ingested and 20 m^3 of air inhaled are generally used when considering exposure for an entire day. However, based on direction from Region 4 of EPA, these assumptions will not be reduced even though the exposure is only for 2 h each day. Using these parameters for a 2-h period will overestimate the actual risks to a roving worker and provide an upper-bound estimate of the associated risks.

A.5. RISK EQUATIONS

Risks and hazards for ingestion, inhalation, dermal contact, and external exposure to radiation were calculated using the equations presented in this section.

Inhalation exposure is evaluated with the following:

$$Intake\ (mg/kg\text{-}d) = C \times IR_a \times (1/VF + 1/PEF) \times EF \times ED\ /(BW \times AT)$$

$$Intake\ (pCi) = C \times IR_a \times (1/VF + 1/PEF) \times ET \times EF \times ED \times Cf_i$$

where

C = Contaminant concentration (mg/kg or pCi/g),
IR_a = Inhalation rate (m^3/d),
PEF = Particulate emission factor (m^3/kg),
VF = Volatilization factor (m^3/kg),
EF = Exposure frequency (d/year),
ED = Exposure duration (years),

AT = Averaging time (d),
BW = Adult body weight (kg),
Cf_i = Conversion factor (g/kg).

Ingestion exposure is evaluated with the following equation:

$$Intake\ (mg/kg\text{-}d) = C \times IR \times EF \times ED / (BW \times AT)$$

$$Intake\ (pCi) = C \times IR \times EF \times ED \times Cf$$

where

C = Contaminant concentration (mg/kg or pCi/g),
IR = Ingestion rate (kg/d),
EF = Exposure frequency (d/year),
ED = Exposure duration (years),
AT = Averaging time (d),
BW = Adult body weight (kg),
Cf = Conversion factor (g/kg).

Dermal contact with contaminated soil is evaluated for chemicals with the following equation:

$$Intake\ (mg/kg\text{-}d) = C \times SA \times CF \times AF \times ABS \times EF \times ED / (BW \times AT)$$

where

C = Contaminant concentration (mg/kg or pCi/g),
SA = Surface area (m^2/event),
CF = Conversion factor ($kg\text{-}cm^2$)/($mg\text{-}m^2$),
AF = Adherence (mg/cm^2),
ABS = Absorption factor (unitless),
EF = Exposure frequency (event/year),
ED = Exposure duration (years),
AT = Averaging time (d),
BW = Adult body weight (kg).

External exposure to ionizing radiation from contaminated soil is evaluated with the following equation:

$$Time\ integrated\ activity\ concentration\ (pCi\text{-}year/g) = CS \times (1\text{-}S_e) \times EF \times ED \times Te$$

where

CS = Contaminant concentration (pCi/g),
S_e = Gamma shielding factor (unitless),
EF = Exposure frequency (d/d),
ED = Exposure duration (years),
Te = Exposure time factor (h/h).

The parameters used in the quantification of exposure are presented in Table A.4. The quantification of receptor exposure forms the basis of the risk calculations.

A.6. CALCULATION OF RISK/HAZARDS

In the risk calculation step, the receptor exposure is compared with benchmark values to determine the probability of adverse health effects.

For carcinogens, risk is calculated as follows:

$$Risk = Intake \times Slope\ Factor$$

where

Risk	=	carcinogenic risk for receptor (unitless),
Intake	=	receptor intake for carcinogenic constituents via pathway under consideration (mg/kg-d),
Slope factor	=	toxicity data specific to the constituent and pathway [risk/(mg/kg-d)].

For non-carcinogens, the hazard is calculated as follows:

$$Hazard = Intake/Reference\ Dose$$

where

Hazard	=	noncarcinogenic hazard for receptor (unitless),
Intake	=	receptor intake for non-carcinogenic constituents via pathway under consideration (mg/kg-d),
Reference dose	=	toxicity data specific to the constituent and pathway (mg/kg-d).

Table A.5 presents the toxicity data used in the calculation of risks/hazards. The risk/hazard results are discussed below.

A.7. RISK/HAZARD RESULTS

Roving worker risks were calculated assuming exposure by ingestion, inhalation, dermal contact, and external exposure to ionizing radiation. Tables A.6 and A.7 present the risks/hazards for a roving worker while moving among all EUs which are accessible.

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP inside rover locations

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Inorganics (mg/kg)												
Aluminum	221/222	8.80E+03	8.80E+03	1.94E+04	1.37E+04	6.13E+02	5.96E+04	2.09E+04	X	2.09E+04	Yes	
Antimony	55/186	5.40E-02	2.50E+01	2.78E+00	3.89E+00	1.62E-01	1.92E+01	3.25E+00	D	3.25E+00	Yes	
Arsenic	216/227	9.00E-01	2.50E+01	1.21E+01	1.05E+01	9.30E-01	1.03E+02	1.32E+01	X	1.32E+01	Yes	
Barium	222/222			8.97E+01	6.49E+01	1.42E+01	5.78E+02	9.69E+01	X	9.69E+01	Yes	
Beryllium	199/221	5.50E-02	7.25E-01	1.58E+00	9.72E+00	1.42E-01	1.45E+02	2.66E+00	X	2.66E+00	Yes	
Boron	21/52	5.50E-01	1.05E+00	2.30E+00	2.85E+00	1.20E+00	1.24E+01	2.96E+00	D	2.96E+00	Yes	
Cadmium	118/223	1.25E-02	1.44E+00	1.40E+00	4.12E+00	1.10E-01	4.83E+01	1.86E+00	X	1.86E+00	Yes	
Calcium	221/221			2.72E+04	5.11E+04	2.36E+02	3.17E+05	3.29E+04	X	3.29E+04	Yes*	Essential nutrient
Chromium	222/224	2.80E-01	3.10E-01	3.31E+01	4.15E+01	4.54E+00	4.82E+02	3.77E+01	X	3.77E+01	Yes	
Chromium, hexavalent	2/61	0.00E+00	1.00E+00	3.90E-01	2.58E-01	5.80E-01	6.00E-01	4.45E-01	D	4.45E-01	Yes	
Cobalt	221/222	6.00E+00	6.00E+00	1.57E+01	1.42E+01	1.22E+00	1.34E+02	1.72E+01	X	1.72E+01	Yes	
Copper	221/222	3.08E+00	3.08E+00	5.51E+01	1.71E+02	4.00E+00	2.20E+03	7.41E+01	X	7.41E+01	Yes	
Cyanide	0/18	2.70E-01	3.60E-01	3.10E-01	2.12E-02			3.19E-01	D	3.19E-01	No	No detects
Iron	222/222			2.86E+04	1.24E+04	5.84E+01	7.96E+04	3.00E+04	X	3.00E+04	Yes*	Essential nutrient
Lead	225/232	1.11E+01	3.54E+01	1.84E+02	2.06E+03	3.50E+00	3.14E+04	4.07E+02	X	4.07E+02	Yes	
Lithium	48/48			2.76E+01	1.74E+01	4.50E+00	8.01E+01	3.40E+01	L	3.40E+01	Yes	
Magnesium	220/221	1.70E+02	1.70E+02	7.24E+03	1.15E+04	1.07E+02	7.38E+04	9.45E+03	L	9.45E+03	Yes*	Essential nutrient
Manganese	222/222			9.30E+02	8.58E+02	3.87E+01	4.91E+03	1.06E+03	L	1.06E+03	Yes	
Mercury	180/236	9.50E-03	1.20E-01	4.40E-01	2.51E+00	2.00E-02	3.27E+01	7.10E-01	X	7.10E-01	Yes	
Molybdenum	18/80	1.65E-01	5.00E+00	1.74E+00	2.51E+00	4.80E-01	1.16E+01	2.21E+00	D	2.21E+00	Yes	
Nickel	225/226	3.68E+00	3.68E+00	7.21E+01	1.92E+02	3.81E+00	2.27E+03	9.32E+01	X	9.32E+01	Yes	
Potassium	226/227	3.83E+02	3.83E+02	2.45E+03	2.89E+03	1.31E+02	1.65E+04	2.98E+03	L	2.98E+03	Yes*	Essential nutrient
Selenium	86/205	1.14E-01	2.50E+01	1.94E+00	3.38E+00	2.28E-01	1.35E+01	2.32E+00	D	2.32E+00	Yes	
Silicon	44/44			5.13E+02	5.19E+02	7.15E+01	2.44E+03	6.68E+02	L	6.68E+02	Yes	
Silver	39/216	3.00E-02	5.25E+00	2.37E+00	2.00E+01	9.40E-02	2.90E+02	4.62E+00	D	4.62E+00	Yes	
Sodium	167/212	6.10E+00	3.56E+02	1.33E+02	3.66E+02	1.04E+01	5.20E+03	1.74E+02	X	1.74E+02	Yes*	Essential nutrient
Strontium	51/51			3.51E+01	6.36E+01	2.70E+00	3.25E+02	5.00E+01	X	5.00E+01	Yes	
Thallium	75/215	5.50E-02	7.80E+01	2.81E+00	6.22E+00	1.40E-01	1.87E+01	3.51E+00	D	3.51E+00	Yes	
Thorium	0/1	1.00E+02	1.00E+02	1.00E+02					D		No	No detects
Tin	16/22	1.80E+00	3.75E+00	4.35E+00	2.32E+00	1.90E+00	9.00E+00	5.48E+00	L	5.48E+00	Yes	
Titanium	1/1			1.70E+02		1.70E+02	1.70E+02		X	1.70E+02	Yes	
Uranium	85/89	2.88E+00	4.50E+00	2.79E+01	1.03E+02	4.00E-01	9.29E+02	4.60E+01	X	4.60E+01	Yes	
Vanadium	217/217			3.94E+01	1.94E+01	4.30E+00	9.55E+01	4.15E+01	X	4.15E+01	Yes	
Zinc	222/222			1.62E+02	7.64E+02	8.30E+00	1.10E+04	2.46E+02	X	2.46E+02	Yes	
Zirconium	1/1			1.10E+01		1.10E+01	1.10E+01		X	1.10E+01	Yes	

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP inside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Phosphorous	40/45	4.00E+00	2.00E+01	7.32E+01	1.20E+02	8.00E+00	4.87E+02	1.03E+02	X	1.03E+02	Yes*	Essential nutrient
Chloride	13/53	2.00E-01	8.00E+02	1.76E+02	1.06E+02	1.10E-01	1.24E+02	2.01E+02	D	1.24E+02	Yes*	Essential nutrient
Fluoride	31/70	2.50E+00	4.00E+01	2.84E+01	3.09E+01	0.00E+00	2.20E+02	3.45E+01	D	3.45E+01	Yes	
Nitrate	14/53	3.00E+00	2.00E+01	1.80E+01	1.82E+01	1.00E-02	1.24E+02	2.21E+01	D	2.21E+01	Yes	
Pesticides/herbicides/polychlorinated biphenyls (mg/kg)												
2,4-D	0/57	6.00E-03	3.25E-01	1.51E-01	3.67E-02			1.59E-01	D	1.59E-01	No	No detects
Silvex	0/57	8.50E-04	4.60E-02	2.18E-02	4.56E-03			2.28E-02	D	2.28E-02	No	No detects
4,4'-DDD	0/90	1.85E-03	1.00E+00	3.89E-02	1.35E-01			6.26E-02	D	6.26E-02	No	No detects
4,4'-DDE	2/90	1.85E-03	1.00E+00	4.10E-02	1.35E-01	5.00E-02	1.50E-01	6.48E-02	D	6.48E-02	Yes	
4,4'-DDT	7/90	1.85E-03	1.00E+00	4.75E-02	1.38E-01	1.90E-02	2.30E-01	7.16E-02	D	7.16E-02	Yes	
Aldrin	1/90	9.00E-04	5.00E-01	1.95E-02	6.70E-02	1.50E-02	1.50E-02	3.12E-02	D	1.50E-02	Yes	
Dieldrin	0/90	1.85E-03	1.00E+00	3.89E-02	1.35E-01			6.26E-02	D	6.26E-02	No	No detects
Endosulfan I	2/90	9.00E-04	5.00E-01	1.95E-02	6.70E-02	1.10E-02	1.20E-02	3.12E-02	D	1.20E-02	Yes	
Endosulfan II	6/90	1.85E-03	1.00E+00	4.33E-02	1.36E-01	2.30E-02	1.70E-01	6.70E-02	D	6.70E-02	Yes	
Endosulfan sulfate	1/90	1.85E-03	1.00E+00	4.17E-02	1.37E-01	2.50E-01	2.50E-01	6.57E-02	D	6.57E-02	Yes	
Endrin	3/90	1.85E-03	1.00E+00	4.26E-02	1.36E-01	2.00E-02	2.30E-01	6.65E-02	D	6.65E-02	Yes	
Endrin aldehyde	0/24	1.85E-03	1.05E-02	2.46E-03	1.72E-03			3.06E-03	D	3.06E-03	No	No detects
Endrin ketone	0/90	1.85E-03	1.00E+00	3.94E-02	1.35E-01			6.30E-02	D	6.30E-02	No	No detects
Heptachlor	1/90	9.00E-04	5.00E-01	1.94E-02	6.70E-02	6.50E-03	6.50E-03	3.11E-02	D	6.50E-03	Yes	
Heptachlor epoxide	5/90	9.00E-04	5.00E-01	2.08E-02	6.76E-02	3.50E-03	1.10E-01	3.27E-02	D	3.27E-02	Yes	
Lindane	1/90	9.00E-04	5.00E-01	1.97E-02	6.70E-02	3.70E-02	3.70E-02	3.14E-02	D	3.14E-02	Yes	
Methoxychlor	2/90	2.05E-03	5.00E+00	1.93E-01	6.70E-01	2.00E-03	2.80E-02	3.10E-01	D	2.80E-02	Yes	
PCB-1016	3/203	1.80E-03	7.00E+00	1.04E-01	5.98E-01	1.20E-01	2.00E-01	1.74E-01	D	1.74E-01	Yes	
PCB-1221	3/203	1.80E-03	9.00E+00	1.39E-01	8.06E-01	1.20E-01	2.00E-01	2.33E-01	D	2.00E-01	Yes	
PCB-1232	3/203	1.80E-03	7.00E+00	1.04E-01	5.98E-01	1.20E-01	2.00E-01	1.74E-01	D	1.74E-01	Yes	
PCB-1242	3/203	1.80E-03	7.00E+00	1.04E-01	5.98E-01	1.20E-01	2.00E-01	1.74E-01	D	1.74E-01	Yes	
PCB-1248	7/203	1.80E-03	7.00E+00	1.05E-01	5.97E-01	4.50E-02	2.00E-01	1.75E-01	D	1.75E-01	Yes	
PCB-1254	56/203	1.80E-03	4.55E+00	2.69E-01	9.34E-01	2.10E-03	1.00E+01	3.77E-01	D	3.77E-01	Yes	
PCB-1260	42/203	1.80E-03	7.00E+00	3.55E-01	3.47E+00	3.10E-03	4.90E+01	7.58E-01	D	7.58E-01	Yes	
PCB-1262	0/1	1.80E-02	1.80E-02	1.80E-02					D		No	No detects
PCB-1268	0/1	1.80E-02	1.80E-02	1.80E-02					D		No	No detects
Toxaphene	0/90	6.00E-02	1.00E+01	4.16E-01	1.34E+00			6.51E-01	D	6.51E-01	No	No detects
alpha-BHC	0/90	9.00E-04	5.00E-01	1.93E-02	6.70E-02			3.11E-02	D	3.11E-02	No	No detects
alpha-Chlordane	1/90	9.00E-04	5.00E+00	1.58E-01	6.04E-01	8.50E-03	8.50E-03	2.63E-01	D	8.50E-03	Yes	
beta-BHC	8/90	9.00E-04	5.00E-01	2.18E-02	6.75E-02	1.20E-02	1.00E-01	3.37E-02	D	3.37E-02	Yes	
delta-BHC	0/90	9.00E-04	5.00E-01	1.93E-02	6.70E-02			3.11E-02	D	3.11E-02	No	No detects
gamma-Chlordane	1/90	9.00E-04	5.00E+00	1.58E-01	6.04E-01	6.00E-03	6.00E-03	2.63E-01	D	6.00E-03	Yes	

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP inside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Semivolatile organic compounds (mg/kg)												
1,2,4-Trichlorobenzene	2/198	2.50E-03	1.75E+01	6.31E-01	1.88E+00	5.10E-02	3.00E+00	8.53E-01	D	8.53E-01	Yes	
1,2-Dichlorobenzene	0/198	2.50E-03	1.75E+01	6.18E-01	1.88E+00			8.39E-01	D	8.39E-01	No	No detects
1,2-Diphenylhydrazine	0/12	1.87E-01	1.75E+01	5.24E+00	5.76E+00			8.22E+00	D	8.22E+00	No	No detects
1,3-Dichlorobenzene	0/198	2.50E-03	1.75E+01	6.18E-01	1.88E+00			8.39E-01	D	8.39E-01	No	No detects
1,4-Dichlorobenzene	2/198	2.50E-03	1.75E+01	6.32E-01	1.89E+00	5.70E-02	3.10E+00	8.53E-01	D	8.53E-01	Yes	
2,2'-Dichlorodiisopropyl ether	1/48	1.75E-01	1.85E+00	2.42E-01	2.40E-01	3.00E-02	3.00E-02	3.00E-01	D	3.00E-02	Yes	
2,3,4,6-Tetrachlorophenol	0/11	6.00E-01	1.75E+01	5.70E+00	5.81E+00			8.87E+00	D	8.87E+00	No	No detects
2,4,5-Trichlorophenol	0/198	1.75E-01	9.00E+01	2.46E+00	9.32E+00			3.55E+00	D	3.55E+00	No	No detects
2,4,6-Trichlorophenol	0/198	1.75E-01	1.75E+01	5.94E-01	1.84E+00			8.10E-01	D	8.10E-01	No	No detects
2,4-Dichlorophenol	1/198	1.75E-01	1.75E+01	6.20E-01	1.88E+00	1.50E-01	1.50E-01	8.40E-01	D	1.50E-01	Yes	
2,4-Dimethylphenol	1/198	1.75E-01	1.75E+01	6.19E-01	1.88E+00	4.10E-02	4.10E-02	8.40E-01	D	4.10E-02	Yes	
2,4-Dinitrophenol	1/198	1.75E-01	9.00E+01	2.47E+00	9.32E+00	3.50E-02	3.50E-02	3.57E+00	D	3.50E-02	Yes	
2,4-Dinitrotoluene	5/198	1.75E-01	1.75E+01	6.33E-01	1.89E+00	2.50E-02	3.20E+00	8.54E-01	D	8.54E-01	Yes	
2,6-Dinitrotoluene	1/198	1.75E-01	1.75E+01	6.19E-01	1.88E+00	4.80E-02	4.80E-02	8.40E-01	D	4.80E-02	Yes	
2-Chloronaphthalene	2/198	1.75E-01	1.75E+01	6.19E-01	1.88E+00	2.50E-02	1.90E-01	8.39E-01	D	1.90E-01	Yes	
2-Chlorophenol	2/198	1.75E-01	1.75E+01	6.48E-01	1.92E+00	5.30E-02	6.00E+00	8.73E-01	D	8.73E-01	Yes	
2-Methyl-4,6-dinitrophenol	0/198	1.75E-01	9.00E+01	2.47E+00	9.32E+00			3.57E+00	D	3.57E+00	No	No detects
2-Methylnaphthalene	27/198	1.75E-01	1.75E+01	6.81E-01	1.91E+00	2.20E-02	3.70E+00	9.06E-01	D	9.06E-01	Yes	
2-Methylphenol	2/198	1.75E-01	1.75E+01	6.18E-01	1.88E+00	2.20E-02	7.00E-02	8.39E-01	D	7.00E-02	Yes	
2-Nitrobenzenamine	1/198	1.75E-01	9.00E+01	2.47E+00	9.32E+00	5.30E-02	5.30E-02	3.56E+00	D	5.30E-02	Yes	
2-Nitrophenol	0/198	1.75E-01	1.75E+01	6.24E-01	1.88E+00			8.45E-01	D	8.45E-01	No	No detects
3,3'-Dichlorobenzidine	2/198	1.75E-01	3.55E+01	1.03E+00	3.69E+00	2.40E-02	5.80E-02	1.47E+00	D	5.80E-02	Yes	
3-Nitrobenzenamine	1/198	1.75E-01	9.00E+01	2.46E+00	9.32E+00	7.00E-02	7.00E-02	3.55E+00	D	7.00E-02	Yes	
4-Bromophenyl phenyl ether	1/198	1.75E-01	1.75E+01	6.19E-01	1.88E+00	9.70E-02	9.70E-02	8.40E-01	D	9.70E-02	Yes	
4-Chloro-3-methylphenol	4/195	1.75E-01	3.55E+01	9.74E-01	3.74E+00	2.50E-02	5.90E+00	1.42E+00	D	1.42E+00	Yes	
4-Chlorobenzenamine	2/198	1.75E-01	3.55E+01	9.38E-01	3.69E+00	2.90E-01	4.20E-01	1.37E+00	D	4.20E-01	Yes	
4-Chlorophenyl phenyl ether	0/198	1.75E-01	1.75E+01	6.20E-01	1.88E+00			8.40E-01	D	8.40E-01	No	No detects
4-Methylphenol	3/198	1.75E-01	1.75E+01	6.17E-01	1.88E+00	2.20E-02	3.50E-02	8.38E-01	D	3.50E-02	Yes	
4-Nitrobenzenamine	1/198	1.75E-01	9.00E+01	2.47E+00	9.32E+00	2.80E-02	2.80E-02	3.57E+00	D	2.80E-02	Yes	
4-Nitrophenol	2/198	1.75E-01	9.00E+01	2.51E+00	9.33E+00	8.50E-02	8.10E+00	3.60E+00	D	3.60E+00	Yes	
Acenaphthene	14/198	1.75E-01	1.75E+01	6.76E-01	1.99E+00	4.30E-02	9.50E+00	9.09E-01	D	9.09E-01	Yes	
Acenaphthylene	20/198	1.75E-01	1.75E+01	6.56E-01	1.89E+00	2.60E-02	3.20E+00	8.78E-01	D	8.78E-01	Yes	
Aniline	0/11	6.00E-01	1.75E+01	5.70E+00	5.81E+00			8.87E+00	D	8.87E+00	No	No detects
Anthracene	32/198	1.75E-01	1.75E+01	6.85E-01	2.00E+00	1.00E-02	1.00E+01	9.20E-01	D	9.20E-01	Yes	
Benz(*a*)anthracene	61/199	3.60E-02	1.75E+01	9.01E-01	2.62E+00	2.80E-02	1.80E+01	1.21E+00	D	1.21E+00	Yes	
Benzenemethanol	0/69	1.75E-01	3.55E+01	2.10E+00	6.05E+00			3.32E+00	D	3.32E+00	No	No detects

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP inside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Benzidine	0/7	1.65E+00	9.00E+01	2.72E+01	3.45E+01			5.25E+01	D	5.25E+01	No	No detects
Benzo(*a*)pyrene	62/199	5.50E-02	1.75E+01	9.90E-01	2.80E+00	3.60E-02	2.20E+01	1.32E+00	D	1.32E+00	Yes	
Benzo(*b*)fluoranthene	69/199	4.90E-02	1.75E+01	1.07E+00	2.99E+00	4.40E-02	2.10E+01	1.42E+00	D	1.42E+00	Yes	
Benzo(*g,h,i*)perylene	44/199	1.75E-01	1.75E+01	8.49E-01	2.38E+00	4.70E-02	1.60E+01	1.13E+00	D	1.13E+00	Yes	
Benzo(*k*)fluoranthene	60/199	5.50E-02	1.75E+01	1.01E+00	2.84E+00	3.90E-02	1.90E+01	1.35E+00	D	1.35E+00	Yes	
Benzoic acid	0/70	4.40E-01	9.00E+01	5.84E+00	1.50E+01			8.83E+00	D	8.83E+00	No	No detects
Bis(2-chloroethoxy)methane	1/198	1.75E-01	1.75E+01	6.19E-01	1.88E+00	3.50E-02	3.50E-02	8.40E-01	D	3.50E-02	Yes	
Bis(2-chloroethyl) ether	2/198	1.75E-01	1.75E+01	6.18E-01	1.88E+00	2.00E-02	2.60E-02	8.39E-01	D	2.60E-02	Yes	
Bis(2-chloroisopropyl) ether	0/150	1.75E-01	1.75E+01	7.40E-01	2.14E+00			1.03E+00	D	1.03E+00	No	No detects
Bis(2-ethylhexyl)phthalate	60/199	1.00E-01	1.75E+01	8.14E-01	2.91E+00	4.40E-02	2.60E+01	1.15E+00	D	1.15E+00	Yes	
Butyl benzyl phthalate	7/198	1.60E-01	1.75E+01	5.99E-01	1.85E+00	1.20E-02	1.20E-01	8.17E-01	D	1.20E-01	Yes	
Carbazole	15/133	1.75E-01	1.20E+01	4.94E-01	1.38E+00	1.20E-02	1.00E+00	6.92E-01	D	6.92E-01	Yes	
Chrysene	68/199	5.00E-02	1.75E+01	1.01E+00	2.76E+00	4.20E-02	2.00E+01	1.33E+00	D	1.33E+00	Yes	
Di-n-butyl phthalate	15/199	1.75E-01	1.20E+01	5.92E-01	1.43E+00	6.20E-02	2.60E+00	7.60E-01	D	7.60E-01	Yes	
Di-n-octylphthalate	4/197	1.10E-01	1.75E+01	5.66E-01	1.82E+00	2.80E-02	1.20E-01	7.80E-01	D	1.20E-01	Yes	
Dibenz(*a,h*)anthracene	19/197	1.75E-01	1.75E+01	6.71E-01	1.92E+00	5.00E-02	3.90E+00	8.97E-01	D	8.97E-01	Yes	
Dibenzofuran	19/198	1.75E-01	1.75E+01	6.53E-01	1.91E+00	4.10E-02	5.40E+00	8.77E-01	D	8.77E-01	Yes	
Diethyl phthalate	3/198	1.75E-01	1.75E+01	6.19E-01	1.88E+00	8.20E-02	4.80E-01	8.39E-01	D	4.80E-01	Yes	
Dimethyl phthalate	1/198	1.75E-01	1.75E+01	5.97E-01	1.85E+00	9.50E-02	9.50E-02	8.15E-01	D	9.50E-02	Yes	
Diphenylamine	2/97	1.75E-01	1.85E+00	2.33E-01	1.90E-01	4.60E-02	5.80E-02	2.65E-01	D	5.80E-02	Yes	
Fluoranthene	77/199	1.75E-01	1.75E+01	1.14E+00	3.39E+00	3.40E-02	2.90E+01	1.54E+00	D	1.54E+00	Yes	
Fluorene	13/198	1.75E-01	1.75E+01	6.61E-01	1.99E+00	6.10E-02	1.00E+01	8.95E-01	D	8.95E-01	Yes	
Hexachlorobenzene	0/198	1.75E-01	1.75E+01	6.20E-01	1.88E+00			8.40E-01	D	8.40E-01	No	No detects
Hexachlorobutadiene	0/198	2.50E-03	1.75E+01	6.18E-01	1.88E+00			8.39E-01	D	8.39E-01	No	No detects
Hexachlorocyclopentadiene	0/198	1.75E-01	1.75E+01	6.20E-01	1.88E+00			8.40E-01	D	8.40E-01	No	No detects
Hexachloroethane	0/198	1.75E-01	1.75E+01	6.20E-01	1.88E+00			8.40E-01	D	8.40E-01	No	No detects
Indeno(*1,2,3-cd*)pyrene	49/199	6.50E-02	1.75E+01	8.95E-01	2.51E+00	4.20E-02	1.80E+01	1.19E+00	D	1.19E+00	Yes	
Isophorone	0/198	1.75E-01	1.75E+01	6.20E-01	1.88E+00			8.40E-01	D	8.40E-01	No	No detects
N-Nitroso-di-n-propylamine	1/198	1.75E-01	1.75E+01	6.33E-01	1.88E+00	2.80E+00	2.80E+00	8.54E-01	D	8.54E-01	Yes	
N-Nitrosodimethylamine	0/11	6.00E-01	1.75E+01	5.70E+00	5.81E+00			8.87E+00	D	8.87E+00	No	No detects
N-Nitrosodiphenylamine	0/101	1.75E-01	1.75E+01	9.89E-01	2.57E+00			1.41E+00	D	1.41E+00	No	No detects
Naphthalene	21/199	1.75E-01	1.75E+01	6.86E-01	1.94E+00	5.30E-02	7.30E+00	9.13E-01	D	9.13E-01	Yes	
Nitrobenzene	1/198	1.75E-01	1.75E+01	6.19E-01	1.88E+00	5.70E-02	5.70E-02	8.40E-01	D	5.70E-02	Yes	
Pentachlorophenol	10/198	1.75E-01	9.00E+01	2.49E+00	9.33E+00	7.40E-02	6.00E+00	3.59E+00	D	3.59E+00	Yes	
Phenanthrene	64/199	9.00E-02	1.75E+01	9.48E-01	2.85E+00	2.80E-02	2.90E+01	1.28E+00	D	1.28E+00	Yes	
Phenol	9/198	1.75E-01	1.75E+01	6.28E-01	1.88E+00	2.30E-02	5.50E+00	8.49E-01	D	8.49E-01	Yes	
Pyrene	81/199	1.75E-01	1.75E+01	1.05E+00	3.09E+00	3.70E-02	2.60E+01	1.42E+00	D	1.42E+00	Yes	

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP inside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Pyridine	0/11	6.00E-01	1.75E+01	5.70E+00	5.81E+00			8.87E+00	D	8.87E+00	No	No detects
Volatile organic compounds (mg/kg)												
(1,1-Dimethylethyl)benzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
(1-Methylpropyl)benzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,1,1,2-Tetrachloroethane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,1,1-Trichloro-2,2,2-trifluoroethane	0/31	2.70E-03	3.80E-03	3.06E-03	2.16E-04			3.12E-03	D	3.12E-03	No	No detects
1,1,1-Trichloroethane	8/188	2.50E-03	7.25E-03	4.08E-03	2.07E-03	2.00E-03	2.40E-02	4.33E-03	D	4.33E-03	Yes	
1,1,2,2-Tetrachloroethane	1/188	2.50E-03	7.25E-03	3.92E-03	1.37E-03	8.60E-04	8.60E-04	4.08E-03	D	8.60E-04	Yes	
1,1,2-Trichloro-1,2,2-trifluoroethane	4/30	2.50E-03	7.50E-03	6.21E-03	3.20E-03	4.00E-03	1.70E-02	7.20E-03	D	7.20E-03	Yes	
1,1,2-Trichloroethane	1/188	2.50E-03	7.25E-03	3.91E-03	1.37E-03	1.00E-03	1.00E-03	4.08E-03	D	1.00E-03	Yes	
1,1-Dichloroethane	4/188	2.50E-03	7.25E-03	3.92E-03	1.38E-03	1.00E-03	5.00E-03	4.08E-03	D	4.08E-03	Yes	
1,1-Dichloroethene	2/188	2.50E-03	7.25E-03	3.94E-03	1.38E-03	2.00E-03	7.00E-03	4.11E-03	D	4.11E-03	Yes	
1,1-Dichloropropene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,2,3-Trichlorobenzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,2,3-Trichloropropane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,2,4-Trimethylbenzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,2-Dibromo-3-chloropropane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,2-Dibromoethane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,2-Dichloroethane	24/188	2.50E-03	7.25E-03	4.25E-03	1.93E-03	2.00E-03	1.20E-02	4.48E-03	D	4.48E-03	Yes	
1,2-Dichloroethene	9/128	2.50E-03	3.80E-03	3.79E-03	4.75E-03	2.00E-03	5.40E-02	4.49E-03	D	4.49E-03	Yes	
1,2-Dichloropropane	1/188	2.50E-03	7.25E-03	3.95E-03	1.37E-03	7.00E-03	7.00E-03	4.11E-03	D	4.11E-03	Yes	
1,2-Dimethylbenzene	2/61	2.80E-03	7.25E-03	5.45E-03	1.39E-03	1.70E-03	3.60E-03	5.74E-03	D	3.60E-03	Yes	
1,3,5-Trimethylbenzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1,3-Dichloropropane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1-Chloro-4-methylbenzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
1-Methyl-4-(1-methylethyl)benzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
2,2-Dichloropropane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
2-Butanone	3/158	2.70E-03	1.05E-02	5.34E-03	2.05E-03	3.00E-03	1.90E-02	5.61E-03	D	5.61E-03	Yes	
2-Hexanone	1/162	2.70E-03	3.20E-02	5.51E-03	2.76E-03	1.30E-02	1.30E-02	5.87E-03	D	5.87E-03	Yes	
4-Methyl-2-pentanone	0/187	2.70E-03	3.20E-02	5.51E-03	2.53E-03			5.82E-03	D	5.82E-03	No	No detects
Acetone	45/168	2.70E-03	1.55E-01	1.44E-02	2.30E-02	3.00E-03	1.20E-01	1.73E-02	D	1.73E-02	Yes	
Benzene	6/189	5.00E-04	7.25E-03	3.85E-03	1.47E-03	4.50E-04	9.20E-03	4.03E-03	D	4.03E-03	Yes	
Bromobenzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
Bromochloromethane	0/49	2.50E-03	7.25E-03	6.08E-03	6.76E-04			6.24E-03	D	6.24E-03	No	No detects
Bromodichloromethane	0/188	2.50E-03	7.25E-03	3.93E-03	1.35E-03			4.09E-03	D	4.09E-03	No	No detects
Bromoform	0/187	2.50E-03	7.25E-03	3.92E-03	1.35E-03			4.08E-03	D	4.08E-03	No	No detects
Bromomethane	0/188	2.70E-03	1.05E-02	5.38E-03	1.60E-03			5.58E-03	D	5.58E-03	No	No detects

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP inside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Butylbenzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
Carbon disulfide	2/187	2.50E-03	6.50E-02	4.28E-03	4.67E-03	2.10E-03	7.00E-03	4.85E-03	D	4.85E-03	Yes	
Carbon tetrachloride	0/188	2.50E-03	7.25E-03	3.93E-03	1.35E-03			4.09E-03	D	4.09E-03	No	No detects
Chlorobenzene	0/187	2.50E-03	7.25E-03	3.92E-03	1.35E-03			4.08E-03	D	4.08E-03	No	No detects
Chloroethane	0/188	2.70E-03	1.05E-02	5.38E-03	1.60E-03			5.58E-03	D	5.58E-03	No	No detects
Chloroform	3/188	2.50E-03	7.25E-03	3.93E-03	1.38E-03	2.70E-04	6.00E-03	4.10E-03	D	4.10E-03	Yes	
Chloromethane	0/188	2.70E-03	1.05E-02	5.38E-03	1.60E-03			5.58E-03	D	5.58E-03	No	No detects
Cumene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
Dibromochloromethane	0/187	2.50E-03	7.25E-03	3.92E-03	1.35E-03			4.08E-03	D	4.08E-03	No	No detects
Dibromomethane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
Dichlorodifluoromethane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
Dimethylbenzene	4/189	2.50E-03	7.25E-03	4.04E-03	2.19E-03	8.40E-04	2.75E-02	4.30E-03	D	4.30E-03	Yes	
Ethylbenzene	2/188	2.50E-03	7.25E-03	3.92E-03	1.35E-03	1.90E-03	5.30E-03	4.08E-03	D	4.08E-03	Yes	
Methylene chloride	83/188	2.70E-03	4.70E-02	7.80E-03	1.08E-02	1.10E-03	1.10E-01	9.10E-03	D	9.10E-03	Yes	
Propylbenzene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
Styrene	0/186	2.50E-03	7.25E-03	3.92E-03	1.35E-03			4.09E-03	D	4.09E-03	No	No detects
Tetrachloroethene	15/187	2.50E-03	7.25E-03	4.20E-03	2.79E-03	7.60E-04	3.10E-02	4.54E-03	D	4.54E-03	Yes	
Toluene	20/189	2.00E-03	7.25E-03	3.95E-03	2.30E-03	3.20E-04	2.40E-02	4.22E-03	D	4.22E-03	Yes	
Trichloroethene	14/188	2.50E-03	7.25E-03	7.71E-03	2.77E-02	2.00E-03	3.20E-01	1.11E-02	D	1.11E-02	Yes	
Trichlorofluoromethane	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
Trichlorotrifluoroethane	0/9	2.70E-03	3.25E-03	2.86E-03	1.67E-04			2.96E-03	D	2.96E-03	No	No detects
Vinyl acetate	0/58	5.50E-03	3.20E-02	6.95E-03	3.37E-03			7.69E-03	D	7.69E-03	No	No detects
Vinyl chloride	0/188	1.05E-03	1.05E-02	5.00E-03	2.22E-03			5.27E-03	D	5.27E-03	No	No detects
cis-1,2-Dichloroethene	0/61	2.50E-03	7.25E-03	5.50E-03	1.33E-03			5.78E-03	D	5.78E-03	No	No detects
cis-1,3-Dichloropropene	0/187	2.50E-03	7.25E-03	3.94E-03	1.35E-03			4.10E-03	D	4.10E-03	No	No detects
o-Chlorotoluene	0/1	2.50E-03	2.50E-03	2.50E-03					D		No	No detects
trans-1,2-Dichloroethene	0/61	2.50E-03	7.25E-03	5.50E-03	1.33E-03			5.78E-03	D	5.78E-03	No	No detects
trans-1,3-Dichloropropene	0/187	2.50E-03	7.25E-03	3.94E-03	1.35E-03			4.10E-03	D	4.10E-03	No	No detects
					Radionuclides (pCi/g)							
Actinium-228	114/116	1.00E-01	1.50E-01	1.28E+00	4.62E-01	3.90E-01	3.10E+00	1.35E+00	X	1.35E+00	No	Daughter
Americium-241	15/130	-8.42E-02	2.80E-01	9.46E-02	4.48E-01	3.71E-02	5.13E+00	1.60E-01	D	1.60E-01	Yes	
Bismuth-212	1/1			1.33E+01		1.33E+01	1.33E+01		X	1.33E+01	No	Daughter
Bismuth-214	85/86	-8.50E-02	-8.50E-02	9.73E-01	4.56E-01	3.32E-01	3.15E+00	1.06E+00	L	1.06E+00	No	Daughter
Cesium-134	0/82	-7.40E-02	8.43E-02	5.49E-03	2.39E-02			9.88E-03	D	9.88E-03	No	No detects
Cesium-137	262/454	-3.79E+00	2.70E+00	1.02E+00	4.47E+00	1.00E-02	4.96E+01	1.37E+00	X	1.37E+00	Yes	
Cobalt-57	2/82	-1.16E+00	1.16E-01	-3.77E-02	2.02E-01	1.59E-01	2.40E-01	-6.13E-04	D	-6.13E-04	Yes	
Cobalt-60	25/432	-1.25E-01	1.90E+00	9.38E-02	2.57E-01	-7.00E-02	1.41E-01	1.14E-01	D	1.14E-01	Yes	

Table A.1. Summary statistics for all measured analytes for the evaluation of surface soil exposures for ETTP inside rover locations (continued)

Analyte	Freq. detect	Min. non-detect conc.	Max. non-detect conc.	Arithmetic mean conc.	Standard deviation	Min. detect conc.	Max. detect conc.	UCL95 on mean	Dist. flag[a]	Exposure point conc.	Proceed with screening?	Justification[b]
Europium-152	0/1	-9.00E-02	-9.00E-02	-9.00E-02					D		No	No detects
Europium-154	0/70	-4.00E-02	1.70E-01	4.64E-02	2.32E-02			5.11E-02	D	5.11E-02	No	No detects
Europium-155	1/1			3.07E+00		3.07E+00	3.07E+00		X	3.07E+00	Yes	
Lead-212	78/79	1.60E-02	1.60E-02	2.69E+00	7.17E+00	2.42E-01	5.58E+01	4.04E+00	X	4.04E+00	No	Daughter
Lead-214	84/86	-8.90E-02	2.29E-01	1.18E+00	6.17E-01	4.21E-01	4.19E+00	1.29E+00	X	1.29E+00	No	Daughter
Neptunium-237	75/283	-1.10E+02	2.00E+02	1.52E+00	1.85E+01	1.20E-02	1.88E+02	3.34E+00	D	3.34E+00	Yes	
Niobium-94	0/68	2.00E-02	1.20E-01	3.71E-02	1.48E-02			4.00E-02	D	4.00E-02	No	No detects
Plutonium-238	19/217	-7.80E+00	2.00E+00	-3.98E-02	7.27E-01	8.30E-03	6.86E-01	4.18E-02	D	4.18E-02	Yes	
Plutonium-239	64/284	-2.55E-01	1.80E+01	9.37E-01	4.28E+00	8.90E-03	4.72E+01	1.36E+00	D	1.36E+00	Yes	
Potassium-40	171/174	8.00E-02	6.74E+01	1.22E+01	7.85E+00	2.42E+00	4.78E+01	1.32E+01	X	1.32E+01	Yes	
Protactinium-234	0/1	-7.02E+01	-7.02E+01	-7.02E+01					D		No	No detects
Protactinium-234m	41/133	-5.37E+02	5.20E+02	1.63E+01	1.09E+02	4.74E-01	7.09E+02	3.19E+01	D	3.19E+01	No	Daughter
Radium-226	160/161	1.15E+00	1.15E+00	1.20E+00	4.62E-01	-8.70E-02	3.67E+00	1.26E+00	X	1.26E+00	Yes	
Radium-228	235/241	7.08E-02	4.49E-01	1.51E+00	3.08E+00	5.29E-02	3.77E+01	1.83E+00	X	1.83E+00	No	Daughter
Ruthenium-106	0/2	2.30E+01	2.52E+01	2.41E+01	1.56E+00			3.10E+01	D	3.10E+01	No	No detects
Strontium-90	42/147	-6.20E-01	1.00E+00	4.65E-01	8.08E-01	3.80E-01	8.20E+00	5.75E-01	D	5.75E-01	Yes	
Technetium-99	157/430	-3.93E+01	5.79E+01	9.20E+01	6.67E+02	-9.18E+00	9.21E+03	1.45E+02	D	1.45E+02	Yes	
Thallium-208	77/79	2.00E-03	3.69E-01	1.07E+00	3.44E+00	7.10E-02	2.58E+01	1.72E+00	X	1.72E+00	No	Daughter
Thorium-228	383/409	-9.03E-02	4.49E-01	1.16E+00	2.43E+00	9.65E-03	3.77E+01	1.36E+00	X	1.36E+00	No	Daughter
Thorium-230	386/407	2.00E-02	6.04E+00	7.73E+00	3.48E+01	1.06E-02	3.16E+02	1.06E+01	X	1.06E+01	Yes	
Thorium-232	392/409	1.93E-03	4.49E-01	1.14E+00	2.43E+00	6.71E-03	3.77E+01	1.33E+00	X	1.33E+00	Yes	
Thorium-234	179/211	-5.33E+01	8.22E+01	5.31E+01	2.38E+02	2.91E-01	2.77E+03	8.02E+01	X	8.02E+01	No	Daughter
Titanium-44	0/69	2.00E-02	1.10E-01	4.32E-02	1.52E-02			4.62E-02	D	4.62E-02	No	No detects
Uranium-234	435/452	-2.45E-01	1.17E+00	1.57E+02	1.01E+03	2.09E-01	1.43E+04	2.36E+02	X	2.36E+02	Yes	
Uranium-235	243/422	-1.41E+00	2.48E+00	1.20E+01	8.12E+01	-1.00E-02	1.34E+03	1.85E+01	X	1.85E+01	Yes	
Uranium-236	44/90	-7.68E-02	2.14E-01	1.09E-01	1.25E-01	3.79E-02	9.32E-01	1.31E-01	D	1.31E-01	Yes	
Uranium-238	438/452	0.00E+00	1.01E+02	2.62E+01	1.16E+02	1.33E-01	1.44E+03	3.51E+01	X	3.51E+01	Yes	

[a]Distribution flags:

D = Not determined because fewer than 5 detects or < 50% detects; t-statistic used in calculations of 95% upper confidence limit on the mean (UCL95).

L = Lognormal; H-statistic used in calculations of UCL95.

N = Normal; t-statistic used in calculations of UCL95.

X = Neither normal nor lognormal; t-statistic used in calculations of UCL95.

[b]Justifications for not proceeding with screening:

No detects = analyte is never detected and is not screened further.

Daughter = short-lived daughter product of isotope that is measured.

Have isotopic data = total activity not considered for further screening due to presence of isotopic data.

[c]Chemical detected in the soil is an essential nutrient; although unlikely to be site-related, this essential nutrient will be screened against background.

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP inside rover locations

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
				Inorganics (mg/kg)					
Aluminum	5.96E+04	7.6E+03	Yes		N/A	4.3E+04	Yes	Yes	
Antimony	1.92E+01	3.1E+00	Yes	1.1E+01	Yes	7.6E-01	Yes	Yes	
Arsenic	1.03E+02	3.9E-01	Yes	3.3E+00	Yes	2.0E+01	Yes	Yes	
Barium	5.78E+02	5.4E+02	Yes	7.4E+03	No	1.5E+02	Yes	Yes	
Beryllium	1.45E+02	1.5E+01	Yes	1.8E-01	Yes	2.0E+00	Yes	Yes	
Boron	1.24E+01	1.6E+03	No	1.7E+04	No	2.8E+01	No	No	Max detect < resid. PRG
Cadmium	4.83E+01	3.7E+00	Yes	3.2E+00	Yes	0.0E+00	Yes	Yes	
Calcium	3.17E+05		N/A		N/A	3.3E+03	Yes	No	Essential nutrient
Chromium	4.82E+02	2.2E+01	Yes	1.5E+02	Yes	5.4E+01	Yes	Yes	
Chromium, hexavalent	6.00E-01	2.2E+01	No	1.5E+02	No	5.4E+01	No	No	Max detect < resid. PRG
Cobalt	1.34E+02	1.4E+02	No		N/A	3.1E+01	Yes	No	Max detect < resid. PRG
Copper	2.20E+03	3.1E+02	Yes		N/A	3.6E+01	Yes	Yes	
Iron	7.96E+04	2.3E+03	Yes		N/A	5.8E+04	Yes	No	Essential nutrient
Lead	3.14E+04	4.0E+02	Yes		N/A	5.8E+01	Yes	Yes	
Lithium	8.01E+01	1.6E+02	No		N/A	3.6E+01	Yes	No	Max detect < resid. PRG
Magnesium	7.38E+04		N/A		N/A	4.4E+03	Yes	No	Essential nutrient
Manganese	4.91E+03	1.8E+02	Yes	3.3E+03	Yes	2.0E+03	Yes	Yes	
Mercury	3.27E+01	2.3E+00	Yes	3.2E+01	Yes	3.5E-01	Yes	Yes	
Molybdenum	1.16E+01	3.9E+01	No	8.8E+02	No	5.3E+00	Yes	No	Max detect < resid. PRG
Nickel	2.27E+03	1.6E+02	Yes	3.3E+03	No	3.6E+01	Yes	Yes	
Potassium	1.65E+04		N/A		N/A	5.0E+03	Yes	No	Essential nutrient
Selenium	1.35E+01	3.9E+01	No	8.9E+02	No	1.1E+00	Yes	No	Max detect < resid. PRG
Silicon	2.44E+03		N/A		N/A	8.3E+02	Yes	Yes	
Silver	2.90E+02	3.9E+01	Yes	7.6E+02	No	0.0E+00	Yes	Yes	
Sodium	5.20E+03		N/A		N/A	4.9E+02	Yes	No	Essential nutrient
Strontium	3.25E+02	4.7E+03	No	9.3E+04	No	2.2E+01	Yes	No	Max detect < resid. PRG
Thallium	1.87E+01	5.2E-01	Yes	7.2E+00	Yes	5.4E-01	Yes	Yes	
Tin	9.00E+00	4.7E+03	No	7.5E+04	No		N/A	No	Max detect < resid. PRG
Titanium	1.70E+02		N/A		N/A		N/A	Yes	
Uranium	9.29E+02	1.6E+00	Yes	5.7E+02	Yes		N/A	Yes	
Vanadium	9.55E+01	5.5E+01	Yes	2.0E+02	No	8.3E+01	Yes	Yes	
Zinc	1.10E+04	2.3E+03	Yes	4.7E+04	No	1.7E+02	Yes	Yes	
Zirconium	1.10E+01		N/A		N/A		N/A	Yes	

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP inside rover locations (continued)

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
Phosphorous	4.87E+02		N/A		N/A		N/A	No	Essential nutrient
Chloride	1.24E+02		N/A		N/A		N/A	No	Essential nutrient
Fluoride	2.20E+02		N/A		N/A		N/A	Yes	
Nitrate	1.24E+02		N/A	2.9E+05	No		N/A	Yes	
Pesticides/herbicides/polychlorinated biphenyls (mg/kg)									
4,4'-DDE	1.50E-01	1.7E+00	No	8.8E+00	No		N/A	No	Max detect < resid. PRG
4,4'-DDT	2.30E-01	1.7E+00	No	8.8E+00	No		N/A	No	Max detect < resid. PRG
Aldrin	1.50E-02	2.9E-02	No	1.5E-01	No		N/A	No	Max detect < resid. PRG
Endosulfan I	1.20E-02	3.7E+01	No	5.4E+02	No		N/A	No	Max detect < resid. PRG
Endosulfan II	1.70E-01	3.7E+01	No	5.4E+02	No		N/A	No	Max detect < resid. PRG
Endosulfan sulfate	2.50E-01	3.7E+01	No	5.4E+02	No		N/A	No	Max detect < resid. PRG
Endrin	2.30E-01	1.8E+00	No	1.9E+00	No		N/A	No	Max detect < resid. PRG
Heptachlor	6.50E-03	1.1E-01	No	6.2E-01	No		N/A	No	Max detect < resid. PRG
Heptachlor epoxide	1.10E-01	5.3E-02	Yes	3.2E-01	No		N/A	Yes	
Lindane	3.70E-02	4.4E-01	No	2.7E+00	No		N/A	No	Max detect < resid. PRG
Methoxychlor	2.80E-02	3.1E+01	No	4.5E+02	No		N/A	No	Max detect < resid. PRG
PCB-1016	2.00E-01	3.9E-01	No	4.8E-01	No		N/A	No	Max detect < resid. PRG
PCB-1221	2.00E-01	2.2E-01	No	5.5E-01	No		N/A	No	Max detect < resid. PRG
PCB-1232	2.00E-01	2.2E-01	No	5.5E-01	No		N/A	No	Max detect < resid. PRG
PCB-1242	2.00E-01	2.2E-01	No	4.6E-01	No		N/A	No	Max detect < resid. PRG
PCB-1248	2.00E-01	2.2E-01	No	5.5E-01	No		N/A	No	Max detect < resid. PRG
PCB-1254	1.00E+01	1.1E-01	Yes	4.9E-01	Yes		N/A	Yes	
PCB-1260	4.90E+01	2.2E-01	Yes	4.8E-01	Yes		N/A	Yes	
alpha-Chlordane	8.50E-03	1.6E+00	No	6.9E+00	No		N/A	No	Max detect < resid. PRG
beta-BHC	1.00E-01	3.2E-01	No	1.6E+00	No		N/A	No	Max detect < resid. PRG
gamma-Chlordane	6.00E-03	1.6E+00	No	6.9E+00	No		N/A	No	Max detect < resid. PRG
Semivolatile organic compounds (mg/kg)									
1,2,4-Trichlorobenzene	3.00E+00	6.5E+01	No	6.6E+02	No		N/A	No	Max detect < resid. PRG
1,4-Dichlorobenzene	3.10E+00	3.4E+00	No	1.4E+02	No		N/A	No	Max detect < resid. PRG
2,2'-Dichlorodiisopropyl ether	3.00E-02	2.9E+00	No	3.6E+03	No		N/A	No	Max detect < resid. PRG
2,4-Dichlorophenol	1.50E-01	1.8E+01	No	3.5E+02	No		N/A	No	Max detect < resid. PRG
2,4-Dimethylphenol	4.10E-02	1.2E+02	No	1.8E+03	No		N/A	No	Max detect < resid. PRG
2,4-Dinitrophenol	3.50E-02	1.2E+01	No	2.5E+02	No		N/A	No	Max detect < resid. PRG
2,4-Dinitrotoluene	3.20E+00	7.2E-01	Yes	4.8E+00	No		N/A	Yes	
2,6-Dinitrotoluene	4.80E-02	7.2E-01	No	4.8E+00	No		N/A	No	Max detect < resid. PRG

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP inside rover locations (continued)

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
2-Chloronaphthalene	1.90E-01	4.9E+02	No	7.2E+03	No		N/A	No	Max detect < resid. PRG
2-Chlorophenol	6.00E+00	6.3E+00	No	4.5E+02	No		N/A	No	Max detect < resid. PRG
2-Methylnaphthalene	3.70E+00		N/A		N/A		N/A	Yes	
2-Methylphenol	7.00E-02	3.1E+02	No	4.5E+03	No		N/A	No	Max detect < resid. PRG
2-Nitrobenzenamine	5.30E-02	1.7E-01	No	3.8E-01	No		N/A	No	Max detect < resid. PRG
3,3'-Dichlorobenzidine	5.80E-02	1.1E+00	No	5.6E+00	No		N/A	No	Max detect < resid. PRG
3-Nitrobenzenamine	7.00E-02		N/A		N/A		N/A	Yes	
4-Bromophenyl phenyl ether	9.70E-02		N/A		N/A		N/A	Yes	
4-Chloro-3-methylphenol	5.90E+00		N/A		N/A		N/A	Yes	
4-Chlorobenzenamine	4.20E-01	2.4E+01	No	3.6E+02	No		N/A	No	Max detect < resid. PRG
4-Methylphenol	3.50E-02	3.1E+01	No	5.2E+02	No		N/A	No	Max detect < resid. PRG
4-Nitrobenzenamine	2.80E-02		N/A		N/A		N/A	Yes	
4-Nitrophenol	8.10E+00		N/A		N/A		N/A	Yes	
Acenaphthene	9.50E+00	3.7E+02	No	4.0E+03	No		N/A	No	Max detect < resid. PRG
Acenaphthylene	3.20E+00		N/A		N/A		N/A	Yes	
Anthracene	1.00E+01	2.2E+03	No	3.3E+04	No		N/A	No	Max detect < resid. PRG
Benz(*a*)anthracene	1.80E+01	6.2E-01	Yes	2.6E+00	Yes		N/A	Yes	
Benzo(*a*)pyrene	2.20E+01	6.2E-02	Yes	2.6E-01	Yes		N/A	Yes	
Benzo(b)fluoranthene	2.10E+01	6.2E-01	Yes	2.6E+00	Yes		N/A	Yes	
Benzo(*g,h,i*)perylene	1.60E+01		N/A		N/A		N/A	Yes	
Benzo(*k*)fluoranthene	1.90E+01	6.2E+00	Yes	2.6E+01	No		N/A	Yes	
Bis(2-chloroethoxy)methane	3.50E-02		N/A		N/A		N/A	Yes	
Bis(2-chloroethyl) ether	2.60E-02	2.1E-01	No	3.8E-01	No		N/A	No	Max detect < resid. PRG
Bis(2-ethylhexyl)phthalate	2.60E+01	3.5E+01	No	9.4E+01	No		N/A	No	Max detect < resid. PRG
Butyl benzyl phthalate	1.20E-01	1.2E+03	No	2.0E+04	No		N/A	No	Max detect < resid. PRG
Carbazole	1.00E+00	2.4E+01	No	1.5E+02	No		N/A	No	Max detect < resid. PRG
Chrysene	2.00E+01	6.2E+01	No	2.5E+02	No		N/A	No	Max detect < resid. PRG
Di-n-butyl phthalate	2.60E+00	6.1E+02	No	1.3E+04	No		N/A	No	Max detect < resid. PRG
Di-n-octylphthalate	1.20E-01	2.4E+02	No	2.4E+03	No		N/A	No	Max detect < resid. PRG
Dibenz(*a,h*)anthracene	3.90E+00	6.2E-02	Yes	2.6E-01	Yes		N/A	Yes	
Dibenzofuran	5.40E+00	2.9E+01	No	4.6E+02	No		N/A	No	Max detect < resid. PRG
Diethyl phthalate	4.80E-01	4.9E+03	No	9.6E+04	No		N/A	No	Max detect < resid. PRG
Dimethyl phthalate	9.50E-02	6.1E+04	No	1.0E+06	No		N/A	No	Max detect < resid. PRG
Diphenylamine	5.80E-02	1.5E+02	No	2.3E+03	No		N/A	No	Max detect < resid. PRG
Fluoranthene	2.90E+01	2.3E+02	No	2.7E+03	No		N/A	No	Max detect < resid. PRG

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP inside rover locations (continued)

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
Fluorene	1.00E+01	2.7E+02	No	3.6E+03	No		N/A	No	Max detect < resid. PRG
Indeno(*1,2,3-cd*)pyrene	1.80E+01	6.2E-01	Yes	2.6E+00	Yes		N/A	Yes	
N-Nitroso-di-n-propylamine	2.80E+00	6.9E-02	Yes	2.3E-01	Yes		N/A	Yes	
Naphthalene	7.30E+00	5.6E+00	Yes	2.7E+01	No		N/A	Yes	
Nitrobenzene	5.70E-02	2.0E+00	No	1.2E+01	No		N/A	No	Max detect < resid. PRG
Pentachlorophenol	6.00E+00	3.0E+00	Yes	2.9E+01	No		N/A	Yes	
Phenanthrene	2.90E+01		N/A		N/A		N/A	Yes	
Phenol	5.50E+00	3.7E+03	No	7.2E+04	No		N/A	No	Max detect < resid. PRG
Pyrene	2.60E+01	2.3E+02	No	2.0E+03	No		N/A	No	Max detect < resid. PRG
				Volatile organic compounds (mg/kg)					
1,1,1-Trichloroethane	2.40E-02	2.0E+02	No	7.6E+02	No		N/A	No	Max detect < resid. PRG
1,1,2,2-Tetrachloroethane	8.60E-04	4.1E-01	No	1.0E+00	No		N/A	No	Max detect < resid. PRG
1,1,2-Trichloro-1,2,2-trifluoroethane	1.70E-02	2.1E+03	No	9.1E+03	No		N/A	No	Max detect < resid. PRG
1,1,2-Trichloroethane	1.00E-03	7.3E-01	No	1.8E+00	No		N/A	No	Max detect < resid. PRG
1,1-Dichloroethane	5.00E-03	5.1E+01	No	1.9E+02	No		N/A	No	Max detect < resid. PRG
1,1-Dichloroethene	7.00E-03	1.2E+01	No	1.3E-01	No		N/A	No	Max detect < resid. PRG
1,2-Dichloroethane	1.20E-02	2.8E-01	No	6.7E-01	No		N/A	No	Max detect < resid. PRG
1,2-Dichloroethene	5.40E-02		N/A	1.0E+03	No		N/A	Yes	
1,2-Dichloropropane	7.00E-03	3.4E-01	No	2.3E+00	No		N/A	No	Max detect < resid. PRG
1,2-Dimethylbenzene	3.60E-03		N/A	2.3E+05	No		N/A	Yes	
2-Butanone	1.90E-02	7.3E+02	No	1.4E+03	No		N/A	No	Max detect < resid. PRG
2-Hexanone	1.30E-02		N/A		N/A		N/A	Yes	
Acetone	1.20E-01	1.6E+02	No	1.2E+04	No		N/A	No	Max detect < resid. PRG
Benzene	9.20E-03	6.0E-01	No	1.6E+00	No		N/A	No	Max detect < resid. PRG
Carbon disulfide	7.00E-03	3.6E+01	No	1.2E+02	No		N/A	No	Max detect < resid. PRG
Chloroform	6.00E-03	3.6E-01	No	5.2E-01	No		N/A	No	Max detect < resid. PRG
Dimethylbenzene	2.75E-02	2.7E+01	No	2.4E+05	No		N/A	No	Max detect < resid. PRG
Ethylbenzene	5.30E-03	8.9E+00	No	2.2E+01	No		N/A	No	Max detect < resid. PRG
Methylene chloride	1.10E-01	9.1E+00	No	2.3E+01	No		N/A	No	Max detect < resid. PRG
Tetrachloroethene	3.10E-02	1.5E+00	No	1.5E+01	No		N/A	No	Max detect < resid. PRG
Toluene	2.40E-02	6.6E+01	No	2.5E+02	No		N/A	No	Max detect < resid. PRG
Trichloroethene	3.20E-01	5.3E-02	Yes	8.0E+00	No		N/A	Yes	
				Radionuclides (pCi/g)					
Americium-241	5.13E+00	2.2E+00	Yes	8.0E+00	No	0.0E+00	Yes	Yes	
Cesium-137	4.96E+01	2.1E-02	Yes	1.0E-01	Yes	1.0E+00	Yes	Yes	

Table A.2. Comparison of maximum detected surface soil analytes to risk-based PRGs[a] and background criteria to determine contaminants of potential concern at ETTP inside rover locations (continued)

Analyte	Max detect conc.	Resid. soil PRG[b]	Max detect > resid. PRG?	Indust. soil PRG[c]	Max detect > indust. PRG?	Backgd. conc.[d]	Max detect > backgd.?	COPC?[e]	Justification
Cobalt-57	2.40E-01	2.1E-01	Yes	1.1E+00	No	0.0E+00	Yes	Yes	
Cobalt-60	1.41E-01	4.5E-03	Yes	2.2E-02	Yes	0.0E+00	Yes	Yes	
Europium-155	3.07E+00	7.1E-01	Yes	3.6E+00	No		N/A	Yes	
Neptunium-237	1.88E+02	9.1E-02	Yes	4.5E-01	Yes	1.9E-01	Yes	Yes	
Plutonium-238	6.86E-01	2.7E+00	No	1.1E+01	No	1.7E-01	Yes	No	Max detect < resid. PRG
Plutonium-239	4.72E+01	2.5E+00	Yes	1.0E+01	Yes	5.1E-02	Yes	Yes	
Potassium-40	4.78E+01	7.1E-02	Yes	3.6E-01	Yes	3.4E+01	Yes	Yes	
Radium-226	3.67E+00	2.8E-03	Yes	6.7E-03	Yes	2.6E+00	Yes	Yes	
Strontium-90	8.20E+00	1.4E+01	No	5.7E+01	No	1.1E+00	Yes	No	Max detect < resid. PRG
Technetium-99	9.21E+03	5.7E+02	Yes	2.3E+03	Yes	0.0E+00	Yes	Yes	
Thorium-230	3.16E+02	2.1E+01	Yes	8.1E+01	Yes	1.9E+00	Yes	Yes	
Thorium-232	3.77E+01	2.4E+01	Yes	9.3E+01	No	2.1E+00	Yes	Yes	
Uranium-234	1.43E+04	1.8E+01	Yes	7.0E+01	Yes	2.2E+00	Yes	Yes	
Uranium-235	1.34E+03	1.6E-01	Yes	8.2E-01	Yes	1.6E+00	Yes	Yes	
Uranium-236	9.32E-01	1.9E+01	No	7.4E+01	No	1.7E-01	Yes	No	Max detect < resid. PRG
Uranium-238	1.44E+03	6.3E-01	Yes	3.1E+00	Yes	2.3E+00	Yes	Yes	

Only detected data passing through the first screen (see Table A.1) are shown.

COPC = contaminant of potential concern.

ETTP = East Tennessee Technology Park.

[a]PRG = preliminary remediation goal, at the 10^{-6} risk level or the 0.1 hazard level (whichever is smaller).

[b]Chemical (i.e., nonradiological) residential PRGs are from U. S. Environmental Protection Agency (EPA) Region IX. Radiological residential PRGs are from Oak Ridge National Laboratory (ORNL).

[c]Chemical and radiological industrial PRGs are from ORNL.

[d]Contaminants never detected in background are assumed to have a background criteria of 0.0 (zero).

[e]Contaminants detected above their respective residential soil PRG and background levels are considered to be COPCs. Detected contaminants without a PRG or background screening value are retained as COPCs.

Table A.3. Type of evaluation of COPCs in surface soil at ETTP inside rover locations

Analyte	Quantitative COPC	Qualitative[a] COPC
	Metals	
Aluminum		✔
Antimony	✔	
Arsenic	✔	
Barium	✔	
Beryllium	✔	
Cadmium	✔	
Chromium	✔	
Copper		✔
Lead		✔
Manganese	✔	
Mercury	✔	
Nickel	✔	
Silicon		✔
Silver	✔	
Thallium	✔	
Titanium		✔
Uranium	✔	
Vanadium	✔	
Zinc	✔	
Zirconium		✔
	Pesticides/herbicides/PCBs	
Heptachlor epoxide	✔	
PCB-1254	✔	
PCB-1260	✔	
	VOCs	
1,2-Dichloroethene	✔	
1,2-Dimethylbenzene	✔	
2-Hexanone		✔
Trichloroethene	✔	
	SVOCs	
2,4-Dinitrotoluene	✔	
2-Methylnaphthalene		✔
3-Nitrobenzenamine		✔
4-Bromophenyl phenyl ether		✔
4-Chloro-3-methylphenol		✔
4-Nitrobenzenamine		✔
4-Nitrophenol		✔
Acenaphthylene		✔
Benz(*a*)anthracene	✔	
Benzo(*a*)pyrene	✔	
Benzo(*b*)fluoranthene	✔	
Benzo(*g,h,i*)perylene		✔
Benzo(*k*)fluoranthene	✔	
Bis(2-chloroethoxy)methane		✔
Dibenz(*a,h*)anthracene	✔	
Indeno(1,2,3-cd)pyrene	✔	
Naphthalene	✔	

Table A.3. Type of evaluation of COPCs in surface soil at ETTP inside rover locations (continued)

Analyte	Quantitative COPC	Qualitative[a] COPC
N-Nitroso-di-n-propylamine	✔	
Pentachlorophenol	✔	
Phenanthrene		✔
Radionuclides		
Americium-241	✔	
Cesium-137	✔	
Cobalt-57	✔	
Cobalt-60	✔	
Europium-155	✔	
Neptunium-237	✔	
Plutonium-239	✔	
Potassium-40	✔	
Radium-226	✔	
Technetium-99	✔	
Thorium-230	✔	
Thorium-232	✔	
Uranium-234	✔	
Uranium-235	✔	
Uranium-238	✔	

[a]Based on the lack of available toxicity information, some COPCs were evaluated qualitatively.
COPC = contaminant of potential concern.
ETTP = East Tennessee Technology Park.
PCB = polychlorinated biphenyl.
SVOC = semivolatile organic compound.
VOC = volatile organic compound.

Table A.4. Parameters for evaluation of exposures to soil at ETTP inside rover locations

Pathway	EF (d/year)	ED (year)	BW (kg)	AT_{carc} (d)	AT_{nonc} (d)	CF (various)[a]	IR_{soil} (kg/d)	FI (unitless)	IR_{air} (m^3/d)	SA (m^2/d)	AF (mg/cm^2)	SE (unitless)	TE (h/h)	$EF_{ext.exp.}$ (d/d)
ETTP rover inside main plant fence														
Ingestion	250	5	70	25550	1825	1000.00	0.000050	1.0						
Dermal	250	5	70	25550	1825	0.01				0.316	1.0			
Inhalation	250	5	70	25550	1825	1000.00			20					
External exposure		5										0.2	2/24	250/365

[a]Conversion factor units:

1000 g/kg for ingestion and inhalation of soil (applies to radionuclides only).

0.01 (kg-cm^2)/(mg-m^2) for dermal exposure to soil [(10^{-6} kg/mg) × (10^4 cm^2/m^2)].

Other factors used:

ABS = dermal absorption factor; value is 0.001 (0.1%) for inorganics and 0.01 (1%) for organics (unitless).

PEF = 5.38E+09 m^3/kg for the inhalation pathway.

VF in m^3/kg is analyte-specific (used for volatile organics only for the inhalation pathway).

ETTP = East Tennessee Technology Park.

Table A.5. Toxicity values[a] for COPCs in surface soil at ETTP inside rover locations

		Non-carcinogenic toxicity values			Carcinogenic toxicity values				Other parameters used		
COPC	G.I. absorp. factor[b]	Oral chronic RfD[c]	Dermal chronic RfD[c]	Inhalation chronic RfD[c]	Oral slope factor[d]	Dermal slope factor[e]	Inhalation slope factor[f]	External exposure slope factor[g]	Dermal ABS factor[h]	PEF[i]	VF[j]
					Non-radionuclides						
1,2-Dichloroethene	0.8	9.00E-03	7.20E-03						0.01	5.38E+09	
1,2-Dimethylbenzene	0.8	2.00E+00	1.60E+00						0.01	5.38E+09	6.80E+03
2,4-Dinitrotoluene	0.85	2.00E-03	1.70E-03		6.80E-01	8.00E-01			0.01	5.38E+09	3.93E+05
Antimony	0.02	4.00E-04	8.00E-06						0.001	5.38E+09	
Arsenic	0.41	3.00E-04	1.23E-04		1.50E+00	3.66E+00	1.51E+01		0.001	5.38E+09	
Barium	0.07	7.00E-02	4.90E-03	1.43E-04					0.001	5.38E+09	
Benz(*a*)anthracene	0.31				7.30E-01	2.35E+00	3.10E-01		0.01	5.38E+09	1.05E+07
Benzo(*a*)pyrene	0.31				7.30E+00	2.35E+01	3.10E+00		0.01	5.38E+09	2.72E+07
Benzo(*b*)fluoranthene	0.31				7.30E-01	2.35E+00	3.10E-01		0.01	5.38E+09	5.13E+06
Benzo(*k*)fluoranthene	0.31				7.30E-02	2.35E-01	3.10E-02		0.01	5.38E+09	4.37E+07
Beryllium	0.01	2.00E-03	2.00E-05	5.71E-06			8.40E+00		0.001	5.38E+09	
Cadmium	0.01	1.00E-03	1.00E-05				6.30E+00		0.01	5.38E+09	
Chromium	0.02	3.00E-03	6.00E-05	2.86E-05			4.20E+01		0.001	5.38E+09	
Dibenz(*a,h*)anthracene	0.31				7.30E+00	2.35E+01	3.10E+00		0.01	5.38E+09	1.16E+08
Heptachlor epoxide	0.72	1.30E-05	9.36E-06		9.10E+00	1.26E+01	9.10E+00		0.01	5.38E+09	5.71E+06
Indeno(*1,2,3-cd*)pyrene	0.31				7.30E-01	2.35E+00	3.10E-01		0.01	5.38E+09	6.33E+07
Manganese	0.04	4.60E-02	1.84E-03	1.43E-05					0.001	5.38E+09	
Mercury	0.07	3.00E-04	2.10E-05						0.001	5.38E+09	
N-Nitroso-di-n-propylamine	0.25				7.00E+00	2.80E+01			0.01	5.38E+09	1.23E+05
Naphthalene	0.8	2.00E-02	1.60E-02	8.57E-04					0.01	5.38E+09	6.19E+04
Nickel	0.27	2.00E-02	5.40E-03						0.001	5.38E+09	
Nitrate	0.5	1.60E+00	8.00E-01						0.001	5.38E+09	
PCB-1254	0.9	2.00E-05	1.80E-05		2.00E+00	2.22E+00	2.00E+00		0.06	5.38E+09	5.89E+05
PCB-1260	0.9				2.00E+00	2.22E+00	2.00E+00		0.06	5.38E+09	4.97E+05
Pentachlorophenol	1	3.00E-02	3.00E-02		1.20E-01	1.20E-01			0.01	5.38E+09	1.31E+06
Silver	0.18	5.00E-03	9.00E-04						0.001	5.38E+09	
Thallium	0.5	8.00E-05	4.00E-05						0.01	5.38E+09	
Trichloroethene	0.15	6.00E-03	9.00E-04		1.10E-02	7.33E-02	6.00E-03		0.01	5.38E+09	3.61E+03
Uranium	0.85	6.00E-04	5.10E-04						0.001	5.38E+09	

Table A.5. Toxicity values[a] for COPCs in surface soil at ETTP inside rover locations (continued)

		Non-carcinogenic toxicity values			Carcinogenic toxicity values				Other parameters used		
COPC	G.I. absorp. factor[b]	Oral chronic RfD[c]	Dermal chronic RfD[c]	Inhalation chronic RfD[c]	Oral slope factor[d]	Dermal slope factor[e]	Inhalation slope factor[f]	External exposure slope factor[g]	Dermal ABS factor[h]	PEF[i]	VF[j]
Vanadium	0.01	7.00E-03	7.00E-05						0.001	5.38E+09	
Zinc	0.2	3.00E-01	6.00E-02						0.001	5.38E+09	
					Radionuclides						
Americium-241	0.0005				9.10E-11		2.81E-08	2.76E-08		5.38E+09	
Cesium-137	1				3.17E-11		1.19E-11	2.55E-06		5.38E+09	
Cobalt-57	0.1				4.85E-13		2.09E-12	3.55E-07		5.38E+09	
Cobalt-60	0.1				7.33E-12		3.58E-11	1.24E-05		5.38E+09	
Europium-155	0.0005				8.07E-13		1.48E-11	1.24E-07		5.38E+09	
Neptunium-237	0.0005				4.92E-11		1.77E-08	7.97E-07		5.38E+09	
Plutonium-239	0.0005				1.21E-10		3.33E-08	2.00E-10		5.38E+09	
Potassium-40	1				1.51E-11		1.03E-11	7.97E-07		5.38E+09	
Radium-226	0.2				2.95E-10		1.16E-08	8.49E-06		5.38E+09	8.00E+00
Technetium-99	0.5				1.32E-12		1.41E-11	8.14E-11		5.38E+09	
Thorium-230	0.0005				7.73E-11		2.85E-08	8.19E-10		5.38E+09	
Thorium-232	0.0005				8.47E-11		4.33E-08	3.42E-10		5.38E+09	
Uranium-234	0.02				5.11E-11		1.14E-08	2.52E-10		5.38E+09	
Uranium-235	0.02				5.03E-11		1.01E-08	5.43E-07		5.38E+09	
Uranium-238	0.02				5.62E-11		9.35E-09	1.14E-07		5.38E+09	

[a]Toxicity data are from http://risk.lsd.ornl.gov/tox/tox_values.html.
[b]Gastrointestinal absorption factor; unitless.
[c]Units for reference doses (RfDs) are mg/kg-d.
[d]Units for oral slope factors are $(mg/kg\text{-}d)^{-1}$ for chemicals and risk/pCi for radionuclides.
[e]Units for dermal slope factors are $(mg/kg\text{-}d)^{-1}$ (for chemicals only).
[f]Units for inhalation slope factors are $(mg/kg\text{-}d)^{-1}$ for chemicals and risk/pCi for radionuclides.
[g]Units for external exposure slope factors are (risk/year per pCi/g) (for radionuclides only).
[h]Dermal absorption factor; unitless (for chemicals only).
[i]Particulate emission factor, in m^3/kg.
[j]Volatilization factor, in m^3/kg (only used for volatile organic compounds).
COPC = contaminant of potential concern.
ETTP = East Tennessee Technology Park.

Table A.6. Cancer risks from exposure to surface soil at ETTP inside rover locations

COPC	EPC[a]	Cancer intakes[b] Ingest.	Dermal	Inhal.	Ext. expos.	Cancer risks Ingest.	Dermal	Inhal.	Ext. expos.	Total	COC?[c]
ETTP inside rover accessible locations											
Arsenic	1.32E+01	4.6E-07	2.9E-08	3.4E-11		6.9E-07	1.1E-07	5.2E-10		8.0E-07	
Beryllium	2.66E+00	9.3E-08	5.9E-09	6.9E-12				5.8E-11		5.8E-11	
Cadmium	1.86E+00	6.5E-08	4.1E-08	4.8E-12				3.0E-11		3.0E-11	
Chromium	3.77E+01	1.3E-06	8.3E-08	9.8E-11				4.1E-09		4.1E-09	
Inorganics pathway total						6.9E-07	1.1E-07	4.7E-09		8.0E-07	
2,4-Dinitrotoluene	8.54E-01	3.0E-08	1.9E-08	2.2E-12		2.0E-08	1.5E-08			3.5E-08	
Benz(*a*)anthracene	1.21E+00	4.2E-08	2.7E-08	3.1E-12		3.1E-08	6.3E-08	9.7E-13		9.4E-08	
Benzo(*a*)pyrene	1.32E+00	4.6E-08	2.9E-08	3.4E-12		3.4E-07	6.9E-07	1.1E-11		1.0E-06	
Benzo(*b*)fluoranthene	1.42E+00	5.0E-08	3.1E-08	3.7E-12		3.6E-08	7.4E-08	1.1E-12		1.1E-07	
Benzo(*k*)fluoranthene	1.35E+00	4.7E-08	3.0E-08	3.5E-12		3.4E-09	7.0E-09	1.1E-13		1.0E-08	
Dibenz(*a,h*)anthracene	8.97E-01	3.1E-08	2.0E-08	2.3E-12		2.3E-07	4.7E-07	7.2E-12		7.0E-07	
Heptachlor epoxide	3.27E-02	1.1E-09	7.2E-10	8.5E-14		1.0E-08	9.1E-09	7.7E-13		2.0E-08	
Indeno(*1,2,3-cd*)pyrene	1.19E+00	4.2E-08	2.6E-08	3.1E-12		3.0E-08	6.2E-08	9.6E-13		9.2E-08	
N-Nitroso-di-n-propylamine	8.54E-01	3.0E-08	1.9E-08	2.2E-12		2.1E-07	5.3E-07			7.4E-07	
PCB-1254	3.77E-01	1.3E-08	5.0E-08	9.8E-13		2.6E-08	1.1E-07	2.0E-12		1.4E-07	
PCB-1260	7.58E-01	2.6E-08	1.0E-07	2.0E-12		5.3E-08	2.2E-07	3.9E-12		2.8E-07	
Pentachlorophenol	3.59E+00	1.3E-07	7.9E-08	9.3E-12		1.5E-08	9.5E-09			2.5E-08	
Trichloroethene	1.11E-02	3.9E-10	2.4E-10	4.3E-08		4.2E-12	1.8E-11	2.6E-10		2.8E-10	
Organics pathway total						1.0E-06	2.3E-06	2.8E-10		3.3E-06	
Chemicals pathway total						1.7E-06	2.4E-06	5.0E-09		4.1E-06	
Americium-241	1.60E-01	1.0E+01		7.4E-04	3.6E-02	9.1E-10		2.1E-11	1.0E-09	1.9E-09	
Cesium-137	1.37E+00	8.5E+01		6.3E-03	3.1E-01	2.7E-09		7.6E-14	8.0E-07	8.0E-07	
Cobalt-57	0.24	14.85		1.1E-3	5.5E-2	7.4E-12		2.3E-15	1.9E-8	1.9E-8	
Cobalt-60	1.14E-01	7.1E+00		5.3E-04	2.6E-02	5.2E-11		1.9E-14	3.2E-07	3.2E-07	
Europium-155	3.07E+00	1.9E+02		1.4E-02	7.0E-01	1.5E-10		2.1E-13	8.7E-08	8.7E-08	
Neptunium-237	3.34E+00	2.1E+02		1.5E-02	7.6E-01	1.0E-08		2.7E-10	6.1E-07	6.2E-07	

Table A.6. Cancer risks from exposure to surface soil at ETTP inside rover locations (continued)

		Cancer intakes[b]				Cancer risks					
COPC	EPC[a]	Ingest.	Dermal	Inhal.	Ext. expos.	Ingest.	Dermal	Inhal.	Ext. expos.	Total	COC?[c]
Plutonium-239	1.36E+00	8.5E+01		6.3E-03	3.1E-01	1.0E-08		2.1E-10	6.2E-11	1.1E-08	
Potassium-40	1.32E+01	8.2E+02		6.1E-02	3.0E+00	1.2E-08		6.3E-13	2.4E-06	2.4E-06	
Radium-226	1.26E+00	7.9E+01		[d]	2.9E-01	2.3E-08		2.9E-06[d]	2.4E-06	5.3E-06	
Technetium-99	1.45E+02	9.1E+03		6.7E-01	3.3E+01	1.2E-08		9.5E-12	2.7E-09	1.5E-08	
Thorium-230	1.06E+01	6.6E+02		4.9E-02	2.4E+00	5.1E-08		1.4E-09	2.0E-09	5.4E-08	
Thorium-232	1.33E+00	8.3E+01		6.2E-03	3.0E-01	7.1E-09		2.7E-10	1.0E-10	7.4E-09	
Uranium-234	2.36E+02	1.5E+04		1.1E+00	5.4E+01	7.5E-07		1.2E-08	1.4E-08	7.8E-07	
Uranium-235	1.85E+01	1.2E+03		8.6E-02	4.2E+00	5.8E-08		8.7E-10	2.3E-06	2.3E-06	
Uranium-238	3.51E+01	2.2E+03		1.6E-01	8.0E+00	1.2E-07		1.5E-09	9.1E-07	1.0E-06	
Radionuclides pathway total						1.1E-06		2.9E-06	9.9E-06	1.4E-05	

[a]EPC = exposure point concentration, defined as the smaller value between the maximum detected concentration and the 95% upper confidence limit of the mean (UCL95); units are mg/kg for chemicals and pCi/g for radionuclides.

[b]Units for cancer intakes are (mg/kg-d) for chemicals; pCi for radiological ingestion and inhalation; and pCi-year/g for external exposure.

[c]COC = contaminant of concern. When the total risk > 10^{-4}, then any individual contaminant with risk > 10^{-6} is a COC. As seen there are no carcinogenic COCs for either receptor.

[d] The intake/risk of Ra-226 is calculated in two steps:

- particulate intake of Ra-226 (PEF= 5.38e9 m3/kg) with risk calculated based on Ra-226+D slope factor, and
- vapor intake of Rn-222 (VF=8 m3/kg) with risk calculated based on Rn-222 slope factor.

Total Ra-226 risk is calculated as the sum of the risks for particulate intake and vapor intake.

COPC = contaminant of potential concern.

ETTP = East Tennessee Technology Park.

PCB = polychlorinated biphenyl.

Table A.7. Non-carcinogenic hazards from exposure to surface soil at ETTP inside rover locations

COPC	EPC[a]	Non-carcinogenic intakes[b]			Hazard quotients				COC?[c]
		Ingest.	Dermal	Inhal.	Ingest.	Dermal	Inhal.	Total	
		ETTP inside rover accessible locations							
Antimony	3.25E+00	1.6E-06	1.0E-07	1.2E-10	4.0E-03	1.3E-02		1.7E-02	
Arsenic	1.32E+01	6.5E-06	4.1E-07	4.8E-10	2.2E-02	3.3E-03		2.5E-02	
Barium	9.69E+01	4.7E-05	3.0E-06	3.5E-09	6.8E-04	6.1E-04	2.5E-05	1.3E-03	
Beryllium	2.66E+00	1.3E-06	8.2E-08	9.7E-11	6.5E-04	4.1E-03	1.7E-05	4.8E-03	
Cadmium	1.86E+00	9.1E-07	5.8E-07	6.8E-11	9.1E-04	5.8E-02		5.8E-02	
Chromium	3.77E+01	1.8E-05	1.2E-06	1.4E-09	6.1E-03	1.9E-02	4.8E-05	2.6E-02	
Manganese	1.06E+03	5.2E-04	3.3E-05	3.9E-08	1.1E-02	1.8E-02	2.7E-03	3.2E-02	
Mercury	7.10E-01	3.5E-07	2.2E-08	2.6E-11	1.2E-03	1.0E-03		2.2E-03	
Nickel	9.32E+01	4.6E-05	2.9E-06	3.4E-09	2.3E-03	5.3E-04		2.8E-03	
Nitrate	2.21E+01	1.1E-05	6.8E-07	8.0E-10	6.8E-06	8.6E-07		7.6E-06	
Silver	4.62E+00	2.3E-06	1.4E-07	1.7E-10	4.5E-04	1.6E-04		6.1E-04	
Thallium	3.51E+00	1.7E-06	1.1E-06	1.3E-10	2.1E-02	2.7E-02		4.9E-02	
Uranium	4.60E+01	2.3E-05	1.4E-06	1.7E-09	3.8E-02	2.8E-03		4.0E-02	
Vanadium	4.15E+01	2.0E-05	1.3E-06	1.5E-09	2.9E-03	1.8E-02		2.1E-02	
Zinc	2.46E+02	1.2E-04	7.6E-06	8.9E-09	4.0E-04	1.3E-04		5.3E-04	
Inorganics pathway total					1.1E-01	1.7E-01	2.8E-03	2.8E-01	
1,2-Dichloroethene	4.49E-03	2.2E-09	1.4E-09	1.6E-13	2.4E-07	1.9E-07		4.4E-07	
1,2-Dimethylbenzene	3.60E-03	1.8E-09	1.1E-09	1.0E-07	8.8E-10	7.0E-10		1.6E-09	
2,4-Dinitrotoluene	8.54E-01	4.2E-07	2.6E-07	3.1E-11	2.1E-04	1.6E-04		3.6E-04	
Heptachlor epoxide	3.27E-02	1.6E-08	1.0E-08	1.2E-12	1.2E-03	1.1E-03		2.3E-03	
Naphthalene	9.13E-01	4.5E-07	2.8E-07	3.3E-11	2.2E-05	1.8E-05	3.9E-08	4.0E-05	
PCB-1254	3.77E-01	1.8E-07	7.0E-07	1.4E-11	9.2E-03	3.9E-02		4.8E-02	
Pentachlorophenol	3.59E+00	1.8E-06	1.1E-06	1.3E-10	5.9E-05	3.7E-05		9.6E-05	
Trichloroethene	1.11E-02	5.4E-09	3.4E-09	6.0E-07	9.0E-07	3.8E-06		4.7E-06	

Table A.7. Non-carcinogenic hazards from exposure to surface soil at ETTP inside rover locations (continued)

COPC	EPC[a]	Non-carcinogenic intakes[b]			Hazard quotients				COC?[c]
		Ingest.	Dermal	Inhal.	Ingest.	Dermal	Inhal.	Total	
Organics pathway total					1.1E-02	4.0E-02	3.9E-08	5.1E-02	
Chemicals pathway total					1.2E-01	2.1E-01	2.8E-03	3.3E-01	

[a]EPC = exposure point concentration, defined as the smaller value between the maximum detected concentration and the 95% upper confidence limit of the mean (UCL95); units are in mg/kg.

[b]Units for non-carcinogenic intakes are mg/kg-d.

[c]COC = contaminant of concern. When the total hazard $\geq$ 1.0, then any individual contaminant with a hazard $\geq$ 0.1 is a COC. As seen there are no non-carcinogenic COCs for either receptor.

COPC = contaminant of potential concern.

ETTP = East Tennessee Technology Park.

PCB = polychlorinated biphenyl.

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